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December 20, 2000
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N8-98-2

THE NATIONAL SHIPBUILDING RESEARCH PROGRAM

Process Modeling to Improve On-Board and On-Block Outfitting Task 9: Final Report

U.S. DEPARTMENT OF THE NAVY
CARDEROCK DIVISION,
NAVAL SURFACE WARFARE CENTER

in cooperation with
Newport News Shipbuilding

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DISCLAIMER

NATIONAL STEEL AND SHIPBUILDING COMPANY
A GENERAL DYNAMICS COMPANY

NSRP PROJECT 8-98-2

Process Modeling to Improve Productivity of On-Board and On-Block Outfitting

Task 9 Deliverable

Final Report

FIRST MARINE INTERNATIONAL LIMITED

SEPTEMBER 2000

FINAL REPORT

CONTENTS

Appendix I – Technical Paper #10 entitled, **"Implementation of an Improved Outfit Process Model"**, submitted to the Society of Naval Architects and Marine Engineers for the 2000 Ship Production Symposium.

Appendix II – Slide presentation for Appendix I, which was presented at the 2000 Ship Production Symposium, August 23-25, 2000, Williamsburg, Virginia.

1. INTRODUCTION

In recent years NASSCO has made considerable progress in improving their performance in ship outfitting. This improvement is leading towards achieving a level of performance, which will be competitive in international commercial shipbuilding. The implementation of on-block and on-unit outfitting techniques, together with the development of workstation-style production information and the introduction of multi-skilled work teams has significantly reduced the outfit production man-hours and cycle time. This improvement has been achieved through a wide variety of highly focused production oriented projects. In support of this project, NASSCO is building on these achievements to create a firm foundation of performance necessary to achieve international competitiveness.

This document forms part of the NSRP Project 8-98-2, Process Modeling to Improve Productivity of On-Board and On-Block Outfitting. The primary objective of the project is to establish a world-class methodology for the definition of outfit interim products, which can be competitively assembled and installed on a vessel in a multi-trade work environment. The development of a hierarchy of outfit interim products, which can be integrated with the steel structure at the optimum time in the assembly process, will significantly improve the performance of on-block and on- board vessel outfitting.

This document constitutes the final report for NSRP Project 8-98-2, Process Modeling to Improve Productivity of On-Board and On-Block Outfitting. The following deliverables should be read in conjunction with this document:

Task 2 Deliverable – Document Current Outfit Production Process Activities,

Task 3 Deliverable – World-Class Outfit Production Process Activities,

Task 4 Deliverable – Perform Comparative Analysis between NASSCO Current and World-Class Outfit Production Process Activities, and

Task 5 Deliverable – Define Generic Outfit Process Model, and

Task 6 Deliverable – Develop Shipyard Specific Outfit Process Model, and

Task 7 Deliverable – Implement Improved Outfit Process Model, and

Task 8 Deliverable – Business Assessment.

The above documents were the basis for the development of the final report for the outfit process model and should be read in conjunction with this document.

2. PROJECT PLAN

NASSCO planned an 18-month project included the documentation of a specific interim product structure, assembly and installation process and demonstrated implementation of the process on a new building program.

In support of this project, NASSCO leveraged the strengths of its project partners, and exploited the combined Project Team knowledge obtained through accomplishment of this project, along with others, to plan and accomplish a synergistic series of project tasks leading to achievement of project goals.

NASSCO was the prime contractor and team leader for this project. NASSCO utilized a Steering Committee comprised of in-house experts from each of the functional areas involved, and also included representatives from First Marine International, (FMI). The purpose of the Steering Committee was to address strategic issues and to ensure all project tasking proceeded in accordance with the plan. The following is a list of the projects primary tasking/deliverables:

Task-1: Establish Shipyard Process Improvement Team

Task-2: Document Current Production Process Activities

Task-3: Document World-Class Production Process Activities

Task-4: Perform Comparative Analysis

Task-5: Define Generic Outfit Process Model.

Task-6: Develop Shipyard Specific Outfit Process Model.

Task-7: Implement Improved Outfit Process Model

Task-8: Perform Business Assessment

Task-9: Final Report and Industry Workshop

3. PROJECT SUMMARY

This objective of this document is to provide a summary of the project and the results. This document principally consists of a compilation of the interim reports submitted during the course of the project. This compilation exists in the body of Appendices I and II which are a technical paper and its accompanying presentation material that were written for, and presented at, the 2000 Ship Production Symposium in Williamsburg, Virginia on Thursday, August 24, 2000.

The primary objective of this NSRP project is to establish a world-class on-block and on-board process by which interim product family components are competitively assembled and installed in a multi-trade work environment for new construction shipbuilding.

Project focus areas were:

-Processes improvement in areas that assemble interim product structures.

-Processes improvement in the On-block and On-board areas that consume interim product structures.

This was accomplished by:

-Documenting current production process activities related to on-block and on-board outfitting.

-Documenting world-class international processes observed and documented during visits to world-class Asian and European shipyards, and related U.S. assembly industries.

-Comparative analysis of Domestic and International processes.

-Definition of a generic outfit product model including sequence of assembly and installation.

-Development and implementation of a shipyard specific outfit process model.

4. BENEFITS TO THE INDUSTRY

This NSRP project was intended to document a world-class process by which interim product family components are competitively assembled and installed in a multi-trade work environment. The primary benefit of this approach is validation of an outfit interim product assembly and installation methodology via application on an actual new building contract. It is anticipated that the approach will support continued cycle time and cost reduction throughout on-block and on-board production phases which is critical for U.S. shipyard re-entry into the commercial shipbuilding market. Additionally, the project resulted in the following benefits to the shipbuilding industry:

- Documentation of NASSCO's current outfit assembly and installation processes
- Documentation of a generic world-class outfit assembly and installation process
- Documentation of a shipyard specific application
- Business assessment of the methodology
- Applicability to both Commercial and Naval programs

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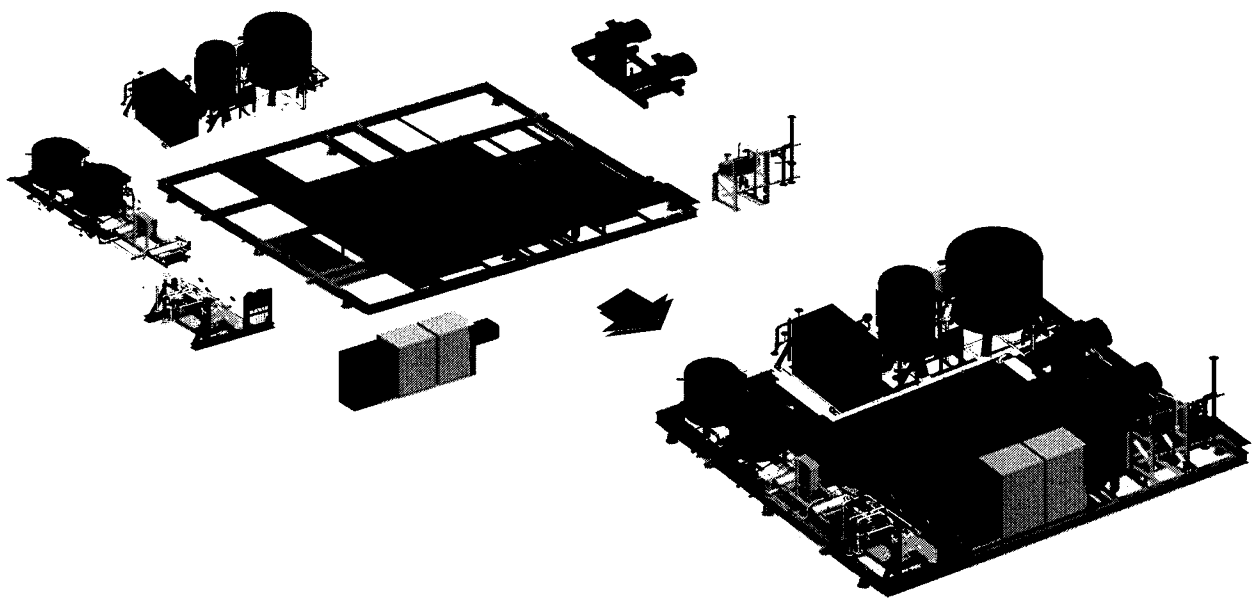
Paper presented at the 2000 Ship Production Symposium, August 24-25, 2000
Williamsburg, Virginia

PAPER 10

Implementation of an Improved Outfit Process Model

Brian E. Altic (V)[1], Richard M. Burns (M)[1], B.J. Fontaine (M)[1], Ian Scott (M)[1], John L. Silveira (M)[1], John Softley (M)[2]



ABSTRACT

National Steel and Shipbuilding Company (NASSCO) has successfully planned and executed several projects directed toward increasing their competitiveness in the shipbuilding marketplace. Among these has been the common goal of implementing outfit design and manufacturing processes that will result in performance improvements. Previous outfit projects such as MARITECH Ship Factory Transformation Project and Parametric Standard Machinery Units have focused on key improvement strategies in targeted shipbuilding process areas with positive results. This paper describes the pilot implementation project that was undertaken to establish an on-block and on-board design and construction process. This is a process by which interim product family components are competitively assembled and installed for new construction shipbuilding. Most of the projects completed by NASSCO thus far have been broadly based, focusing on overall development of standard products and processes. This project placed a further focus on these, along with manufacturing processes, workstation definition, production information and multi-skilled trade's people. These combined elements have been seen as the logical next steps towards process competitiveness

[1] National Steel and Shipbuilding Company, San Diego, California, US.
[2] First Marine International Ltd., London, UK.

INTRODUCTION

In recent years NASSCO has improved its performance in ship outfitting. This improvement is leading towards an increasing competitiveness in shipbuilding. The implementation of on-block and on-unit outfitting process lane techniques and processes has reduced the outfit production man-hours and cycle time. This improvement has been achieved through a wide variety of highly focused production oriented projects. In support of this project, NASSCO is building on these achievements to create a firm foundation of ongoing improvement.

A recent project, funded under the MARITECH program, developed an overall methodology for a product-oriented approach to outfit design and production based on a 'ship factory' concept. This has provided the necessary structure and cohesion by which future projects can be organized and managed for maximum benefit.

This document focuses on the implementation aspects of National Shipbuilding Research Program (NSRP) Project 8-98-2, Process Modeling to Improve Productivity of On-Board and On-Block Outfitting. The primary objective of the project is to establish a methodology for the definition of outfit interim products, which can be competitively assembled and installed. The development of a hierarchy of outfit interim products, which can be integrated with the steel structure at the optimum time in the assembly process, will improve the performance of on-block and on- board vessel outfitting.

This paper describes various elements of the project leading up to and including the implementation plan of the pilot. These elements include:

- Discussion of NASSCO's current outfitting pre-production and production processes.
- Defining a number of the process activities required to implement a product-oriented ship factory.
- Design activities and lessons learned through the course of the project.
- Business assessment.

The focus of the pilot was on an area of the Engine Room on the SeaLift New Construction program. Specifically, the 34'-7" flat, starboard side, aft. Within this area of the ship are systems that support the Ships Service Diesel Generators along with other specific ships functional systems. The area is part of a major grand-block that includes the generator flat which spans from side shell to side shell at the 34'-7" flat. The pilot focused on a large outfitting block/machinery unit in this area along with its interfacing outfit and structure. The machinery unit was commonly known as Pipe Unit #707 (PU-707).

TRADITIONAL PRODUCTION PROCESSES

Traditionally, outfitting is carried out during the later stages of construction such as the pre-outfitting of completed steel blocks and on-board installation.

Traditional pre-outfitting involves the installation of outfit parts onto the steel units and blocks prior to erection. Consequently, the only facility requirement is for additional lay-down area to allow for the pre-outfitting activity.

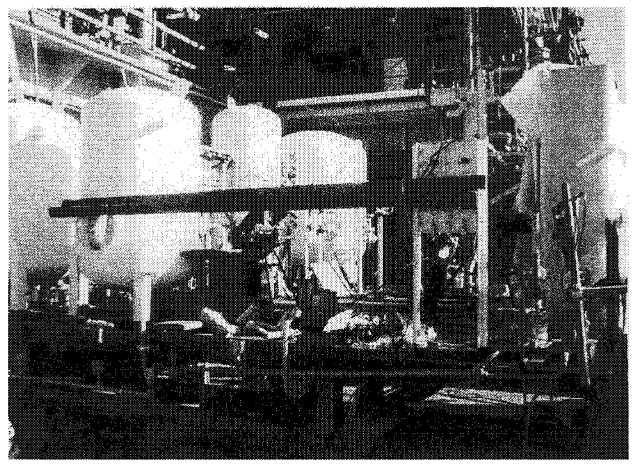


Figure 1 - Unit 707 original design

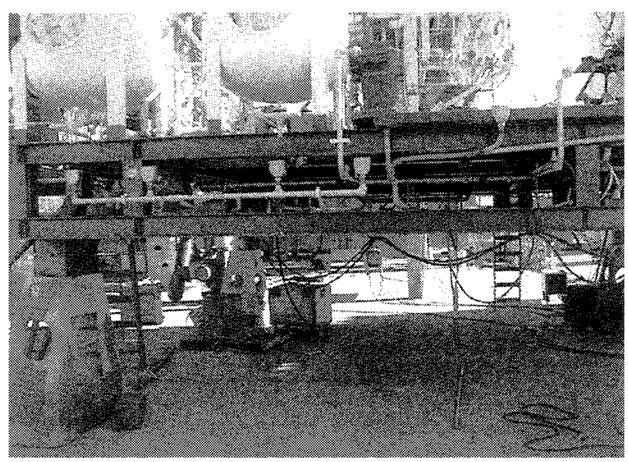


Figure 2 - Unit 707 original design – deck level

This section focuses on the current production processes associated with PU-707. The outfitting unit consists of a foundation made up of angles, beams, and deck plates that support distributive systems, tanks, and equipment for the Starting, Control, and Ships Service Air systems; Lube Oil Transfer system; Stern Tube Lip Tank and Electrical Group Control Center, Load Centers, and

Display Panel. Figures 1 and 2 show PU-707 during various stages of the traditional outfitting fabrication process in the On-Block area.

A subcontractor fabricates the unit foundation. It is then shipped by barge because it is too large for over the road transportation. It is then set on stands, as shown in Figure 2, which allows for access to outfit below the deck plates. This elevated working area requires safety rails and staging. The layout of the equipment locations is then performed, followed by landing the equipment onto the framework. The various equipment is landed to its specified location and either bolted or welded to the structural framework. The distributive system piping is then installed in the following sequence: 1) Service and Control Air, 2) Start Air, 3) Ship Service Diesel Generator (SSDG) Lube Oil, 4) Stern Tube Lube Oil.

Pipe spools are fabricated in NASSCO's pipe shop and sent to the outfitting location on large pallets. The current process defines piping which is ¾" and below as field run. Field run piping is fabricated on the job site instead of the shop. The operations involved in installing pipe to the unit include:

- An inventory of material.
- Researching the production information for locations.
- Layout the locations.
- Staging the piping with wedges, blocks, and tacked pipe hangers.
- Connecting the piping using bolted, welded, and compression fittings.
- Final fitting and welding of the pipe hangers.

The electrical installation operations are similar to the previously described piping operations where inventory, research, layout, and cable support installation are performed in the field. In parallel with the piping, the electrical hot work, followed by the electrical equipment installation, cable installation, and then cable hook up is performed. The completed outfitting assembly then requires an extensive paint touch up, followed by prepping for erection.

The completed pipe unit is then erected onto the generator flat which consists of two steel blocks joined together to create a grand block. Attached to the bottom of the unit are telescoping pipe pedestal foundations which allows the unit to be adjusted vertically. The unit placement is adjusted to optimize the alignment of piping connections between itself and the generator flat grand block.

Finally, after the generator flat grand block is erected onto the ship along with the surrounding hull blocks, the remaining piping connections and main cable feeds are installed and system testing is performed.

Facility

The SLNC program utilizes several outfitting units similar to Pipe Unit 707 in the construction of the ship. All of these large units are currently outfitted in the on-block area shown in Figure 3. This On-Block area along with the On-Board areas has suitable crane and utility services.

Work Force

The On-Board and On-Block area work force is primary made up of specific trades persons to install steel and outfitting materials to the blocks and units. Pipe fitters, electricians, painters, ship fitters, welders, and machinists participate in the installation activities. The work content includes field fitted and welded pipe joints, complex cable terminations and hook ups, fitting and welding of foundations and supports, templating and drilling holes, and epoxy paint coating systems.

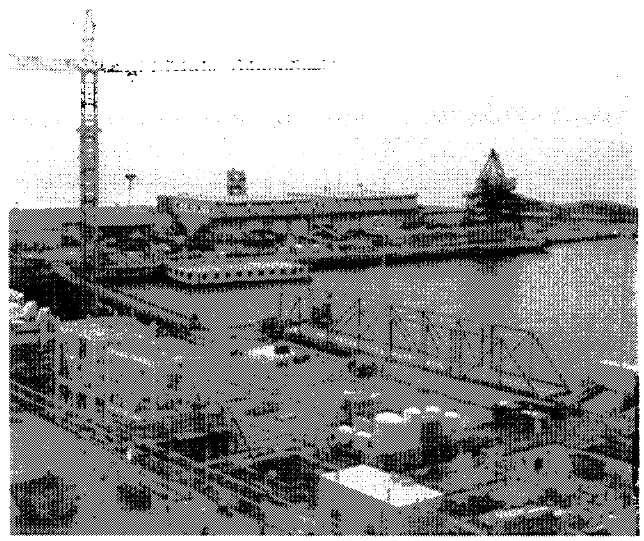


Figure 3 - Outfit unit assembly area

TRADITIONAL DESIGN APPROACH

The traditional approach to unit design begins in the Machinery Arrangement process. At this stage, functionally related equipment, systems and tanks are located to reduce distributed system footage and maximize unitization potential. The goal is to identify the largest possible assembly of equipment and outfitting components that can be completed off the ship, assembled concurrently with the block and easily lifted without exceeding crane-lifting capacities. The final unit content and layout is confirmed by a series of studies, build strategy and preliminary system routing. Each unit is then assigned to a designer for detail development. The detail design process begins with the Metal Outfitting Designer

creating the basic unit structure. He is then followed approximately two weeks later by the piping and electrical designers. Due to several factors including the abilities and expertise of each individual designer, the units on any given vessel are generally treated as unique. As a result of the inherent complexity of the equipment and structural arrangement, important features such as access and lifting requirements are often considered as an afterthought leading to a less then efficient design. At design completion the drawing and parts list is handed to a planner who assigns the material content to multiple construction pallets by trade and production budgets are assigned.

MODERN DESIGN PROCESS

Recent developments in ship production technology are leading to the development of a fully integrated steel and outfit construction process. This means that steel and outfit interim products are combined at the optimum stage in the build process. It is possible to combine parts and assemblies of all types at various construction stages in a series of interim products that match the capabilities of the production processes. Adopting an interim product structure for outfitting requires a significant change in technology to that needed for traditional pre-outfitting of blocks. An integrated assembly methodology with a defined outfit interim product structure requires highly organized processes lanes and workstations for outfit product assembly, as shown in Figure 4. Such a product-oriented workstation philosophy also requires that the design and engineering process be similarly product-oriented in both organization and what they create. That is to say, a hierarchy of multi-system assemblies or interim products must be pre-defined and applied during the design and engineering process. These interim products being integrated at the optimum time in the assembly and construction cycle to minimize cost and cycle time.

Implementing a product-oriented approach

To develop this approach; a generic interim product structure is first generated based upon the constraints of the facility and optimization of the production processes and is used to reflect the impact of an interim product structure throughout the design and engineering process.

The generic interim product structure is applied

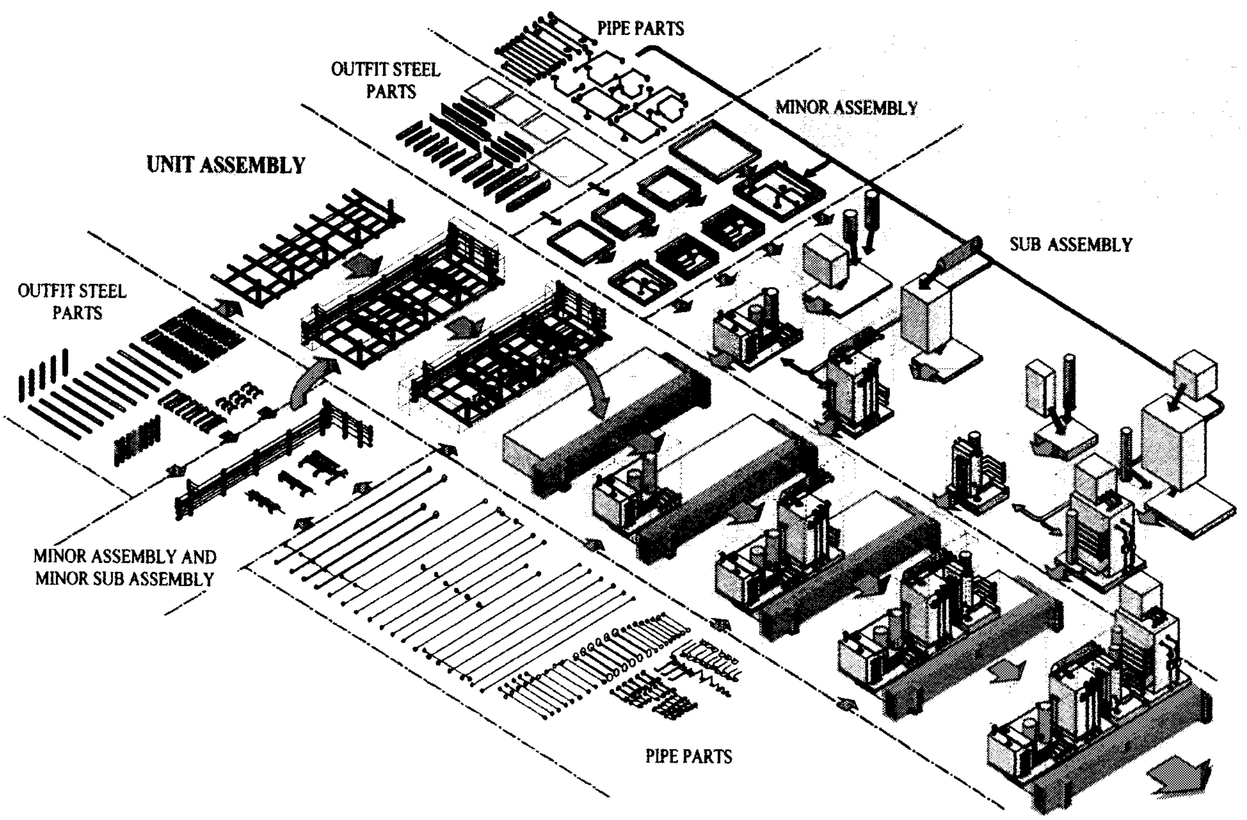


Figure 4 - World class outfit assembly process flow

during the design of a new vessel. The use of pre-defined interim products may reduce the lead-time and man-hours traditionally associated with the development of a new ship design. Also, having a defined product structure enables the implications of a change in product, method or process to be fully analyzed prior to implementation on a live contract and reduces the extent of production unknowns, inherent in a traditional system oriented approach.

To ensure a consistent application of the interim product structure, a series of design rules and decision making criteria are attached as attributes to each of the interim products. These provide a set of work instructions, which are developed, for each interim product, at each stage of the design process. In this manner the production engineering intent is incorporated at the earliest concept design stage and subsequently developed with increasing levels of detail throughout the design process.

Throughout this design process the shipbuilding policy and build strategy provides the designers with a series of work instructions. This ensures that the design of a specific vessel or interim product optimizes the utilization of facilities, processes and manpower as well as meeting the functional requirements of the owner and regulatory bodies. This approach was used in the development of the new design for Unit 707 and piloted the approach for the new, product-oriented processes described in this paper.

REVISED PRODUCT MODEL

As was discussed previously one of the first steps in establishing a product orientated approach is to develop an interim product structure. After several iterations a product hierarchy was adopted. This product structure was based on multiple factors such as interim product size, work content, defined production processes and ship system functionality.

One of the major constraints that had to be dealt with was the fact that the selected pipe unit would be installed on board a follow-on ship. This meant that the interfaces and spatial constraints were fixed. Physical location of each of the pieces of equipment, overall dimensions and interface connections could only be modified slightly from previous hulls.

The original design was modified with the following objectives in mind:

- Create lower tier (smaller and more repeatable) assemblies wherever possible.
- Install all outfitting in easily accessible locations.
- Provide hinged floor plate access and cable tray support to remotely located cable.
- Provide pipe spool adjustment at foundation or hanger in lieu of field welds.
- Rack pipe where possible.

The primary focus was on reducing the amount of time and man-hours it would take to erect and install the material at the on-block and on-board locations. In applying the adopted product hierarchy the new product model evolved into that which is shown in Figure 5. This figure shows an exploded view of the pipe unit and its assemblies at the higher levels. Each of these products can be taken down to the next levels in the hierarchy. An example of this is shown in Figure 6 using the SSDG lube oil transfer sub assembly.

The revised product model optimized the number of assemblies that were created. This product structure allowed for a repeatability of assemblies. Flanged make-ups between assemblies, equipment, and unit interfaces were maximized. All local electrical cable trays, which were previously undocumented and installed on-board after erection, were moved from underneath the unit structure to the perimeter. This moved the work to a different stage of construction and an easier location for the trades' person to install the cabling. Safety was also improved by eliminating awkward maneuvers in tight spaces. The number of parts was reduced. Make-ups were designed to be flexible.

Support trades such as the rigging department were brought into the design process to eliminate work that is traditionally done late in the construction process. The rigging engineer provided input to the design by locating lifting points for safest transportation of the assembly and sub-assemblies. Pad eyes were included in the design at the specified locations. Outfitting interference was designed away from these locations as much as possible.

The foundation vendor was brought into the process early in order to incorporate its specific production processes into the design. Considerations for over the road transportation of the various structural components were included.

PILOT IMPLEMENTATION PLAN

To measure relative success of the project, a pilot implementation plan was developed. This plan included a schedule of necessary actions required to take place in order to ensure a seamless insertion of the pilot into an ongoing shipbuilding program.

The plan included meetings with the internal and external production personnel that would be building the interim products to solicit appropriate feedback into the design and the planning process. The plan also established an Industrial Engineering time study in order to evaluate the pilot and collect data needed to conduct a meaningful cost analysis and lessons learned feedback loop.

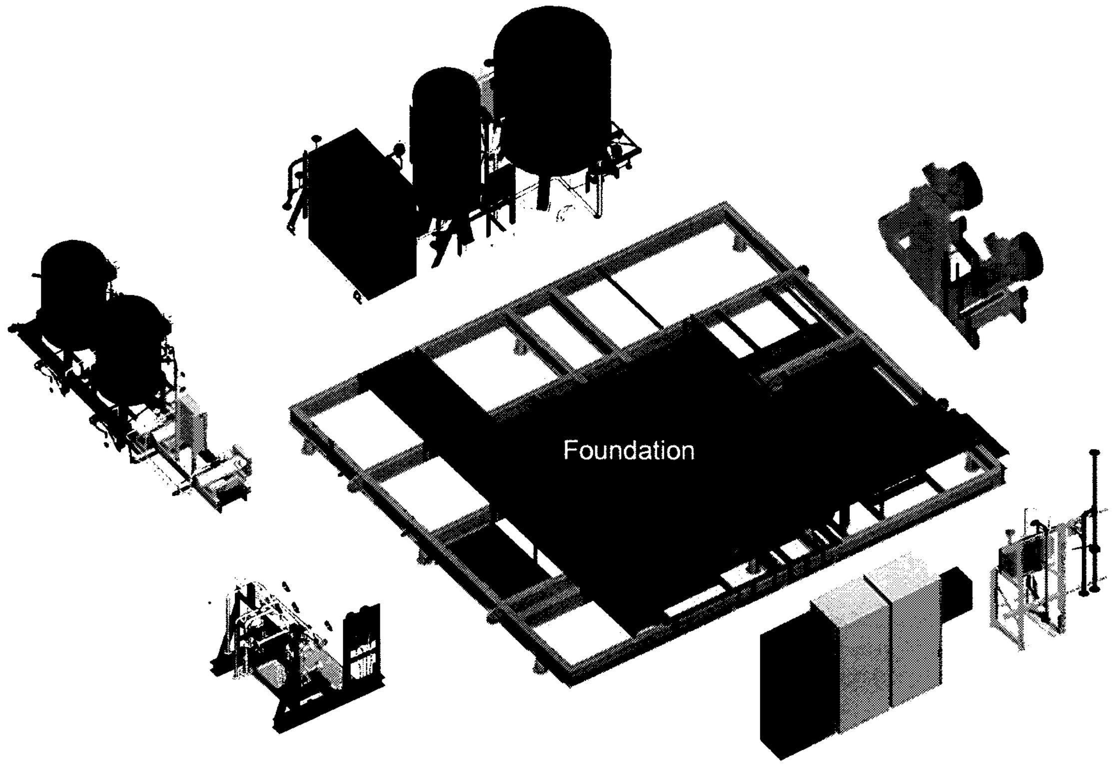


Figure 5 - Unit 707 product breakdown

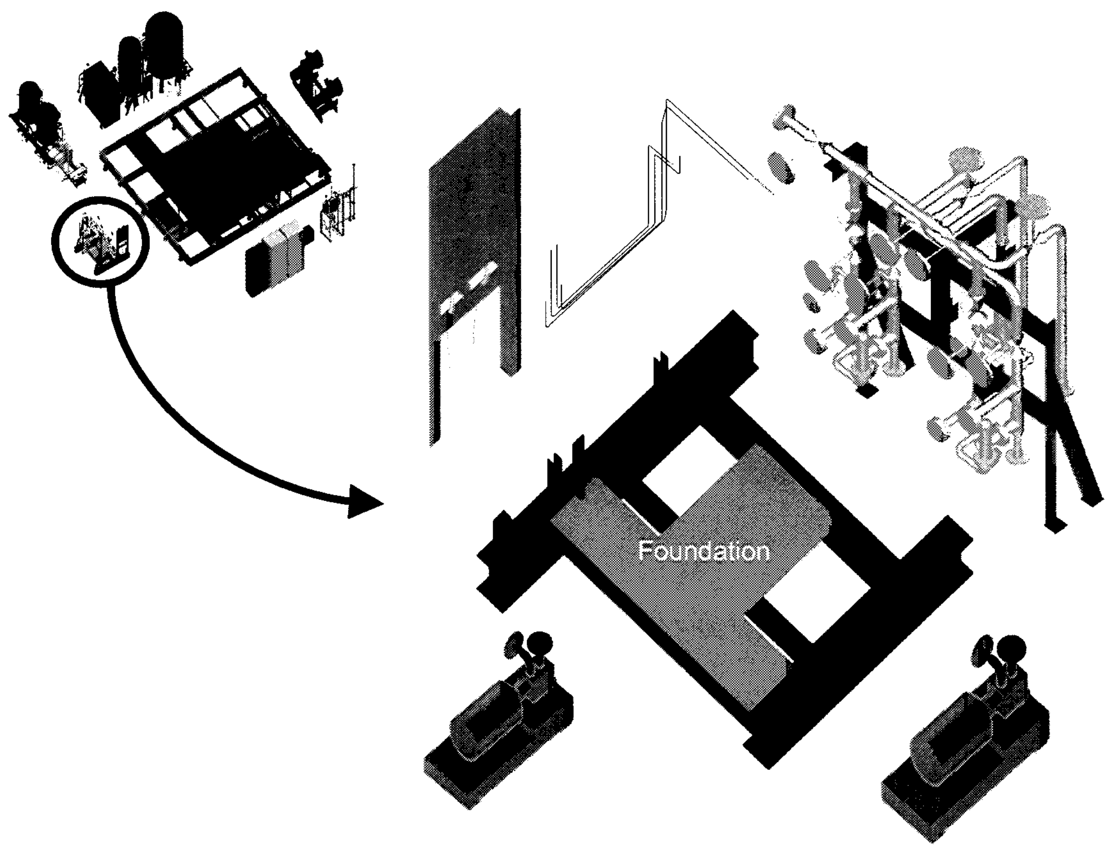


Figure 6 – SSDG lube oil transfer sub-assembly product breakdown

Production Information

Production staff was included early in the design process to provide input to the build strategy and to assist in the identification of the required production information at each stage of construction. Drawing formats were created based on integrated planning/engineering documentation. Using this format allowed the display of components in the proper location and orientation without clouding the drawing with information not pertinent to that specific stage of construction.

As with any new process or methodology, training is imperative. Training is not only important for the introduction of a new process into the organization but from the point of ensuring the approach is implemented in an orderly and consistent fashion. Throughout the course of the project the team members gathered and compiled both written and graphical material to be used in the training process. This training material was not focused on one individual group, but on the company as a whole. Not only would the designer need to be familiar with the outfitting process from an interim product perspective, but production would need to be aware of the modified format of the production information that would be used to construct Pipe Unit 707. Additionally, the concepts would need to be relayed to all departments within NASSCO and to all levels of the organization. This was necessary to solicit support for the current pilot along with providing information about the overall concept to facilitate appropriate decision making when it came to developing long range facility planning and anticipated manning levels along with providing information to cost engineering for marketing purposes.

LESSONS LEARNED

During the course of the pilot it became obvious that a clear definition of an interim product hierarchy and the existence of a product family album was needed to reach agreement as to the defining criteria for each of the levels of the product hierarchy. The creation of a series of previously established products or a product family album, which could be built with established production processes would make the pre-production evolution much quicker and more cost effective.

Another issue that had to be handled by the team was the fact that this design was to be integrated with an ongoing program, which introduces all the challenges of change control.

BUSINESS ASSESSMENT

NASSCO's long range goal is to reduce cost and cycle time to increase competitiveness. This type of a goal will require continuous improvement in all areas.

Based on the pilot, incremental improvement over the normally expected learning curve is anticipated through:

- incorporation of design improvements
- reapportionment of work to a better work center
- reduction in the number of hangers by incorporating the function into product structure
- fitting and welding processes done in a work center dedicated to those processes
- Production information dedicated to the work cell

FUTURE IMPROVEMENTS

Finally, to achieve the goals it is important to ensure all developments in products, processes, skills and knowledge is harnessed in a consistent manner leading towards a common goal. It must be remembered that whenever, one part of the shipbuilding equation changes then the rest must change to balance the overall process.

SUMMARY

This project focused on developing the processes for implementation of a product-oriented, concept in ship outfitting. The key to realizing this is a solid understanding of product-oriented philosophy by actual experience of each stage of the process through a pilot project. It is achieved through the implementation of all stages of the approach in both pre-production and production and the establishment of a 'management of change' organization to control the development and introduction of technology.

While the pilot project is aimed at developing specific parts of the overall concept, using a current contract to not only improve performance but provide valuable experience. In the longer term, a number of factors will affect the full implementation of the approach, including:

- The ability of company management, supervision and the workforce to assimilate the new philosophy.
- Market factors, specifically timeliness of a new design and build contract.
- The availability of investment capital for training, pilot projects and facility development.

Some factors are outside the company's direct control, such as when new contracts will be signed and to

some extent, the time scale required to bring new facilities online, it is believed that the approach is practical and achievable and from the knowledge gained to-date will provide the Company a foundation for significant performance improvement.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the sponsorship and assistance provided by the project steering committee, Mr. Peter E. Jaquith, Mr. John A. Lyle and Mr. Steve Streifer. Additionally, the authors acknowledge the guidance and expertise of the project technical advisor, Mr. Shuji Sato and the project technical consultant Mr. Malcolm Bell. Finally, the authors acknowledge the National Shipbuilding Research Program that has supported these and similar developments within the U.S. Industry.

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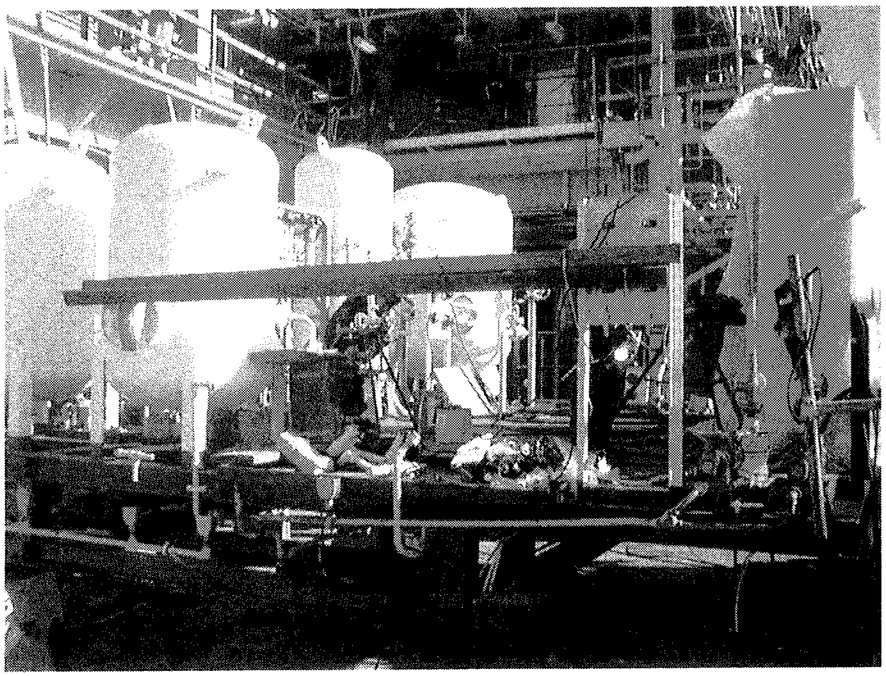
Implementation of an Improved Outfit Process Model

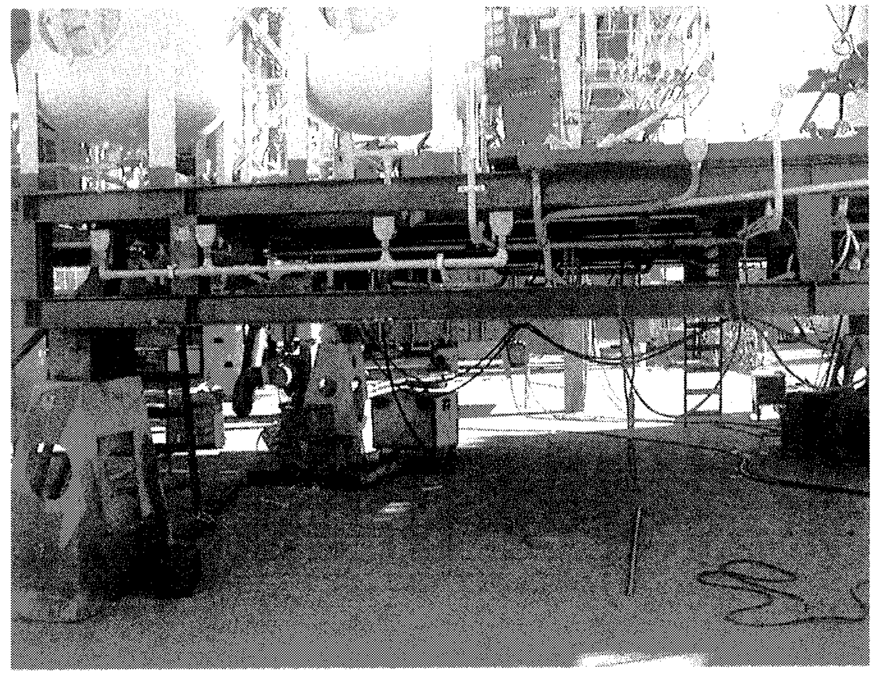
Presented by Ian Scott

Introduction

- NSRP 8-98-2 Contract Award
  - December 1998
- Project Participants
  - NASSCO (National Steel and Shipbuilding Company)
  - FMI (First Marine International LTD)
- Objective - Establish a world-class on-block and on-board process by which interim product family components are assembled and installed.

Original Design





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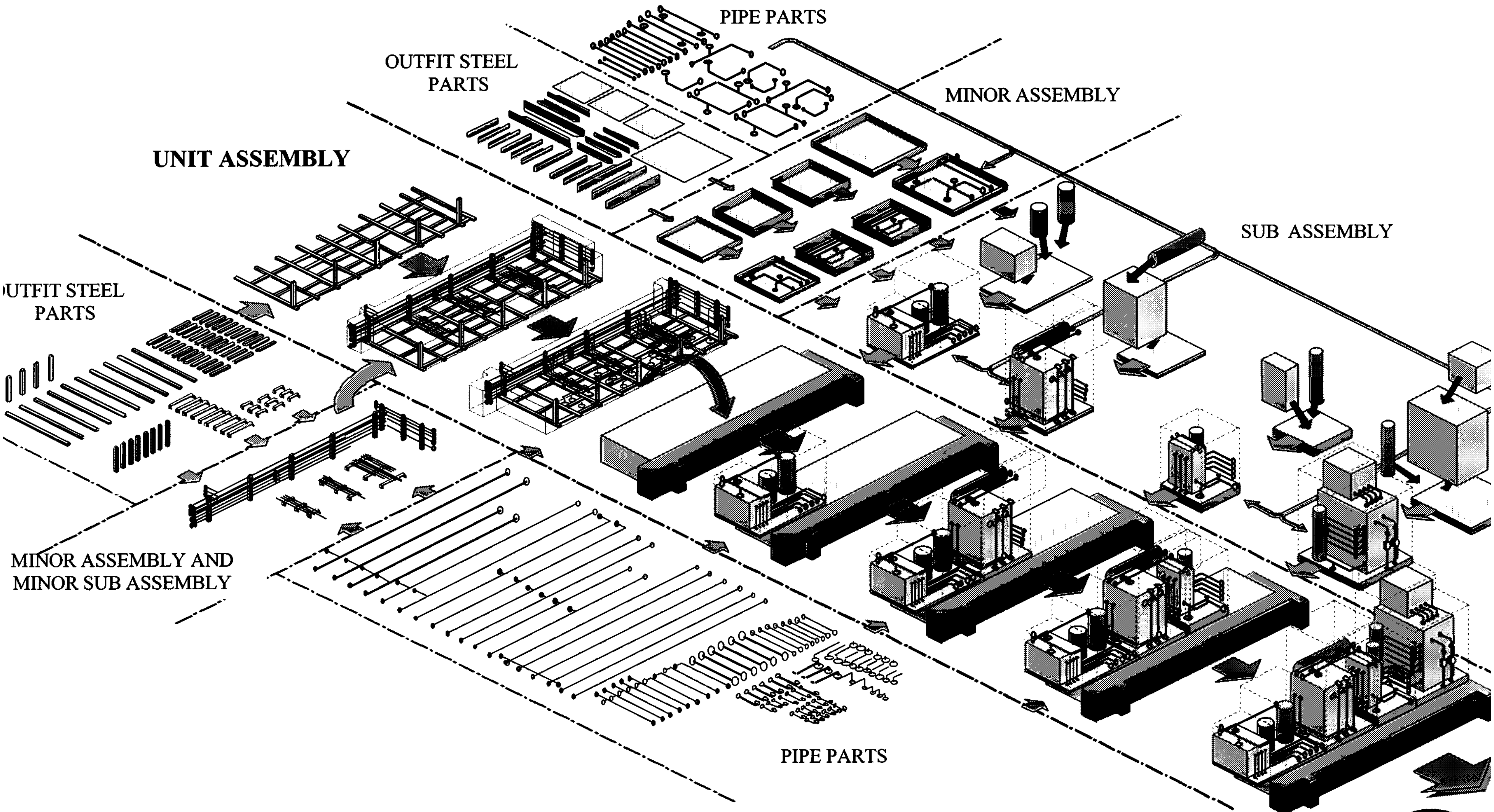
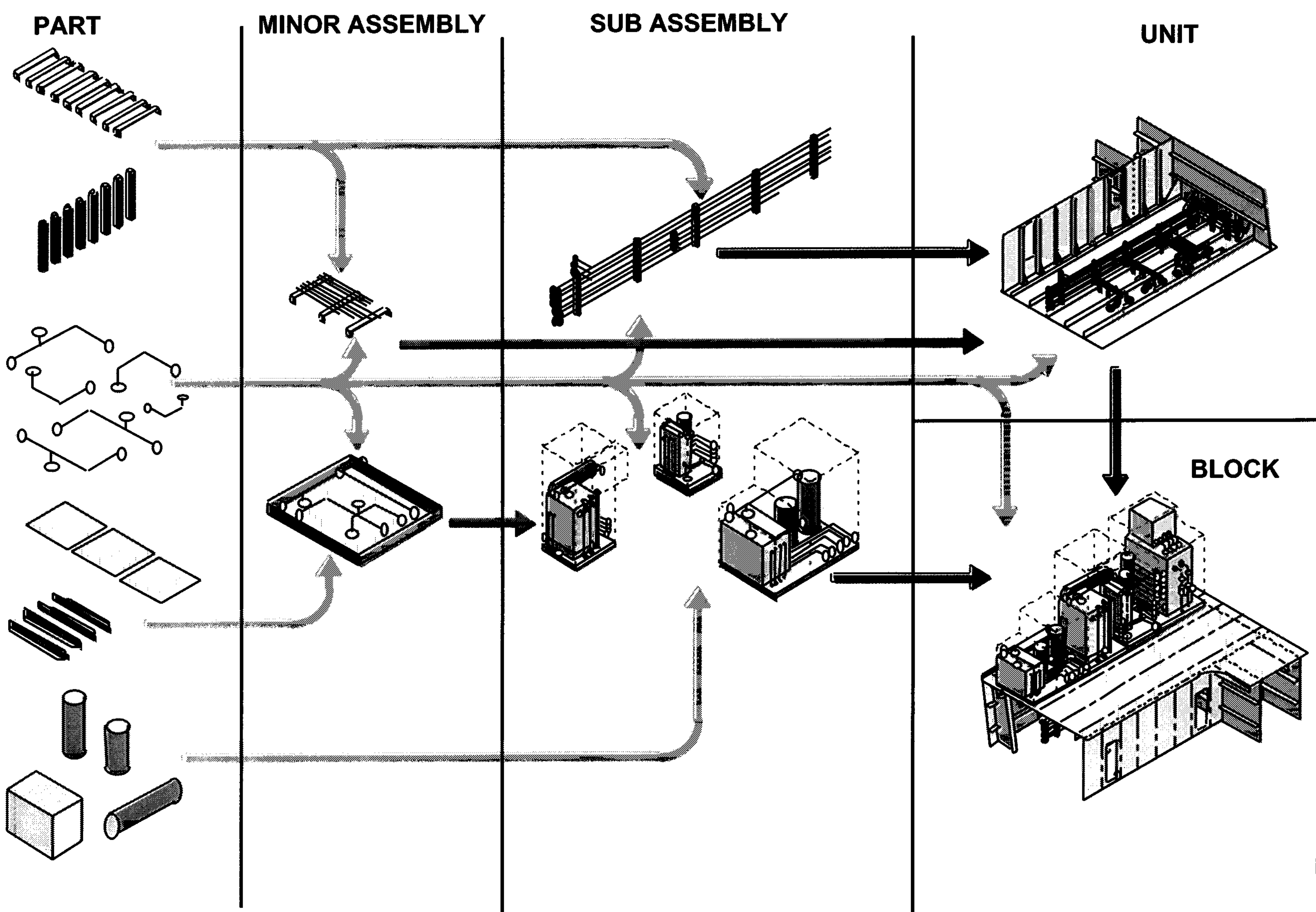
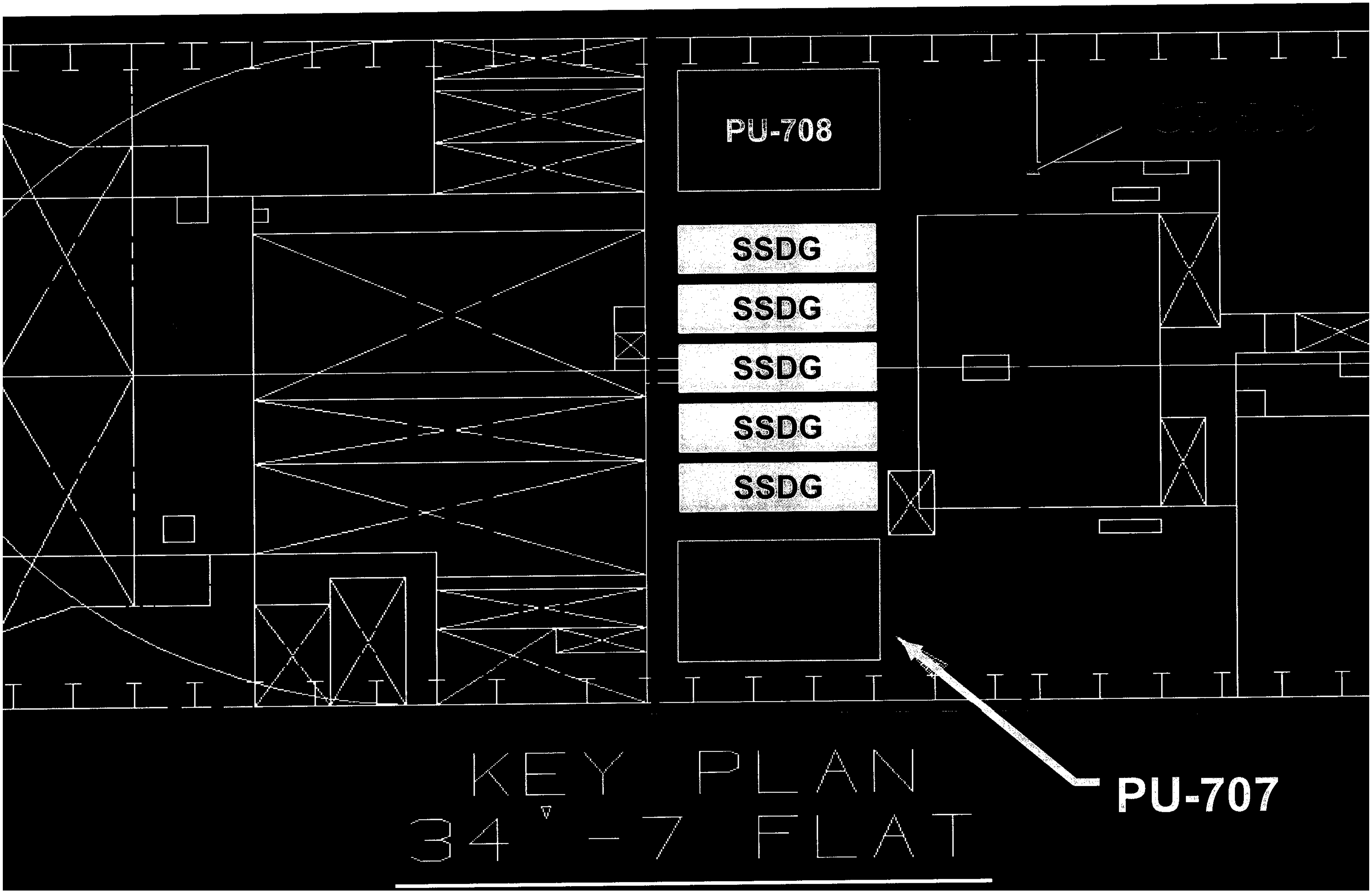
Interim Product Assembly Proces



Outfit Interim Product Structure



Pilot Focus



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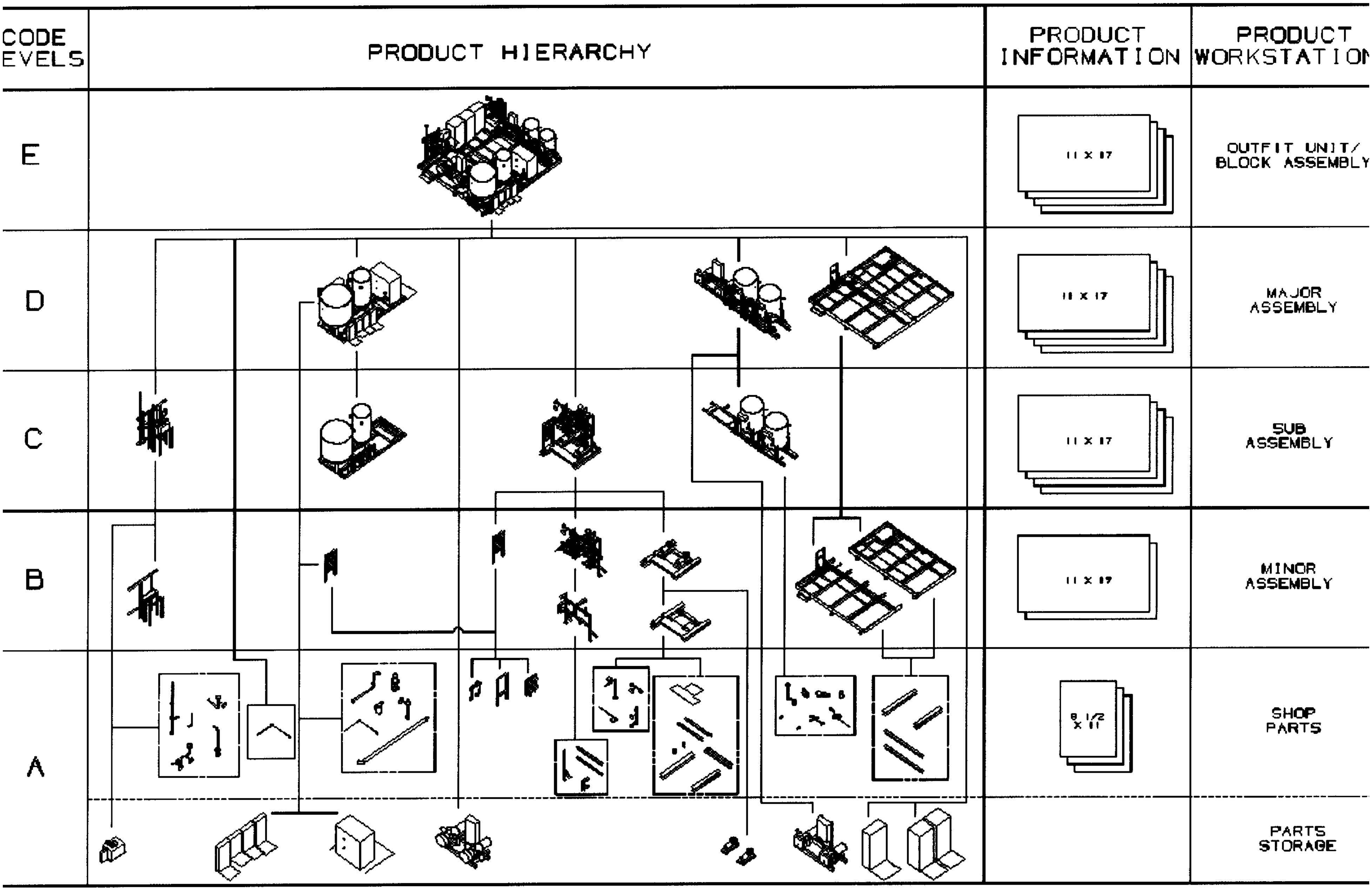
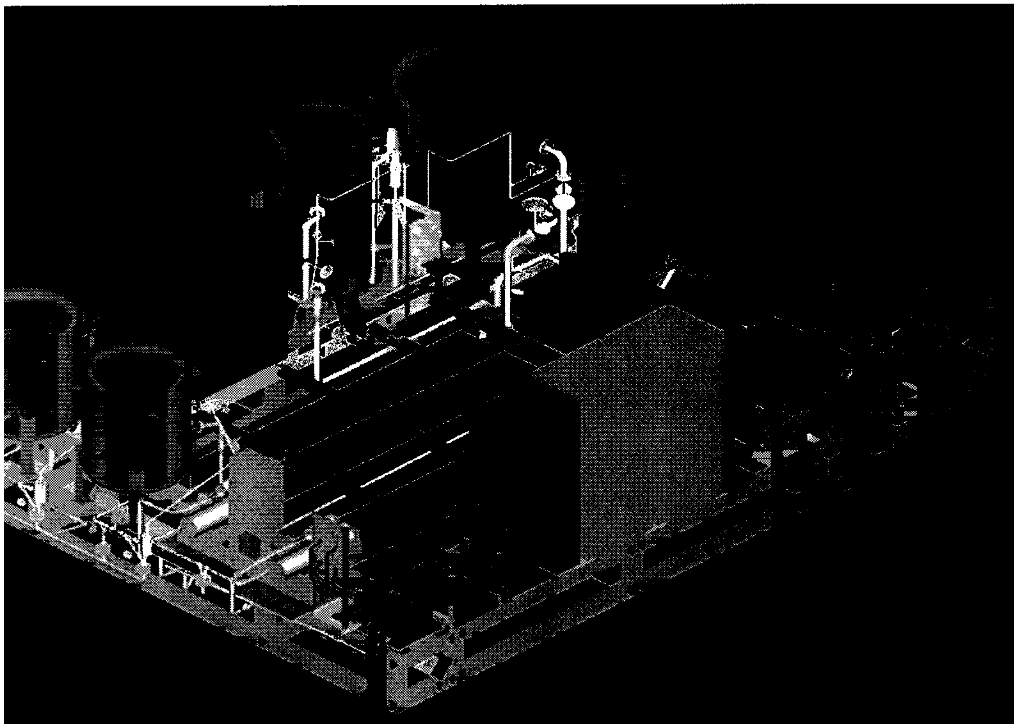
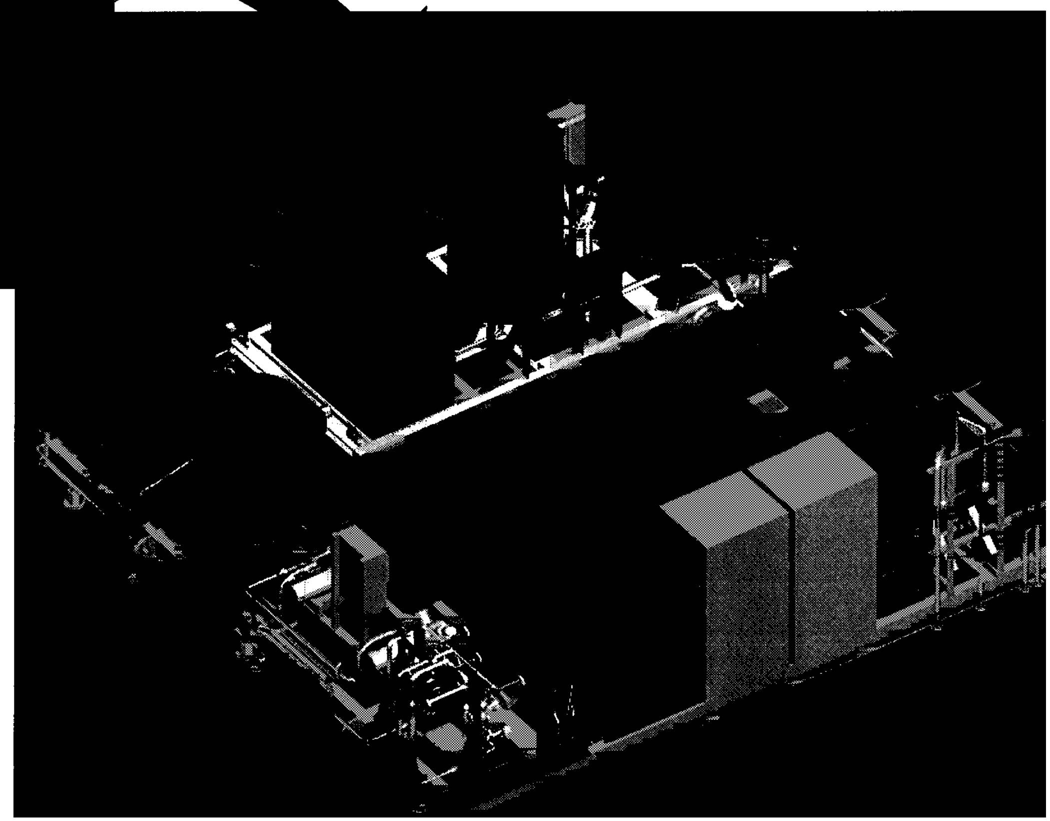
EXPO

Unit 707 Interim Product Tree

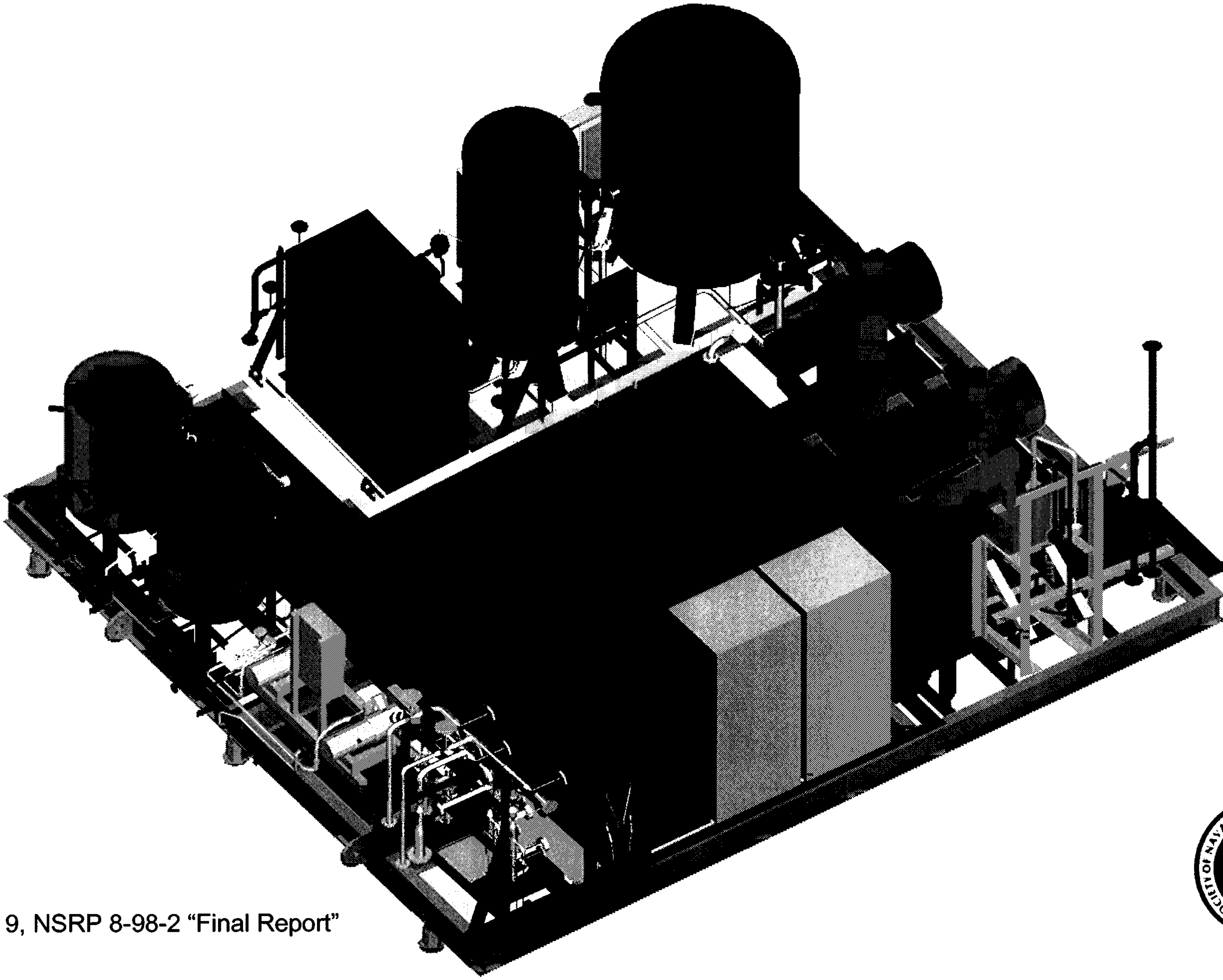


Revised Model

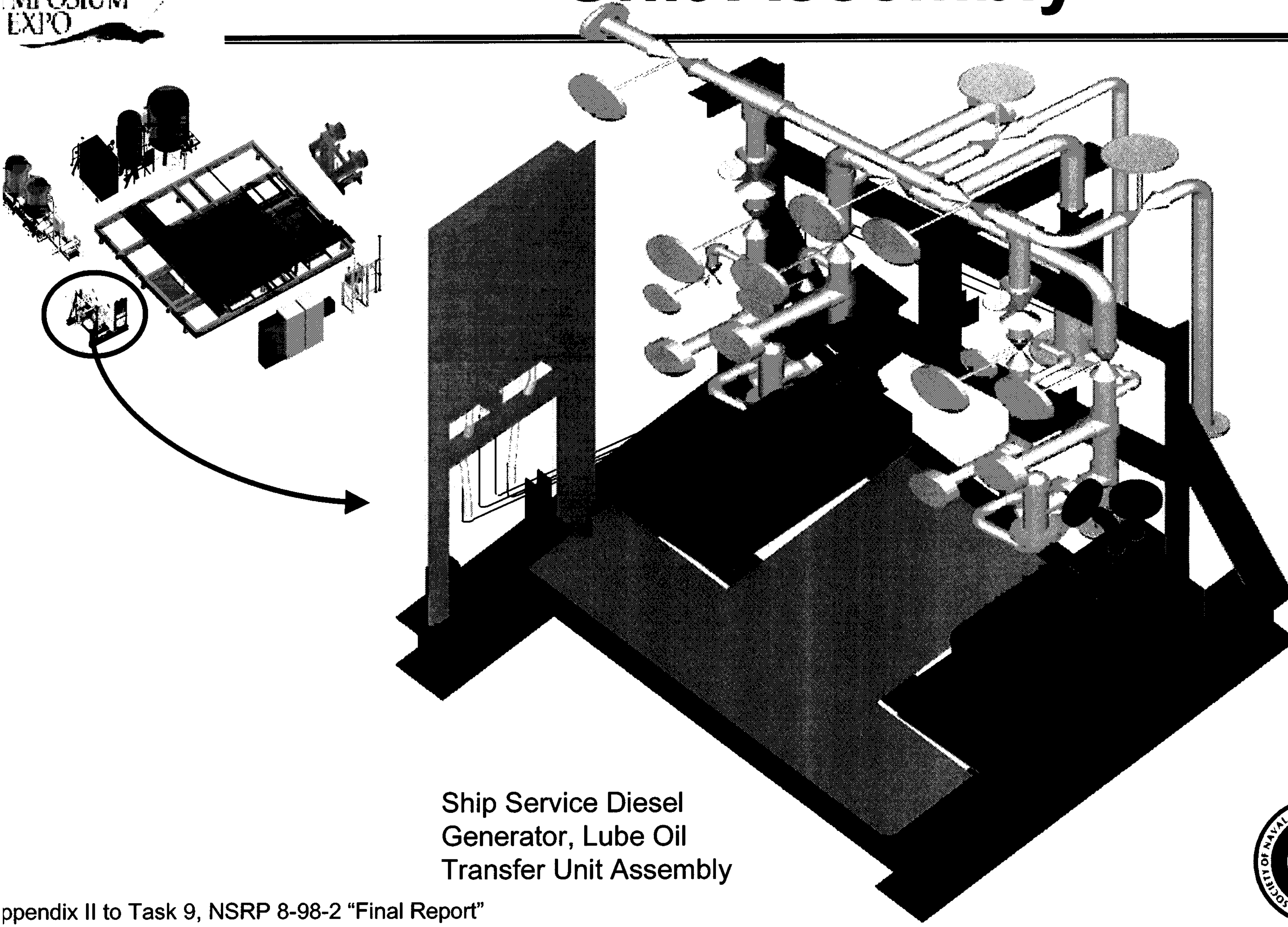




PU-707 Interim Product Approacl

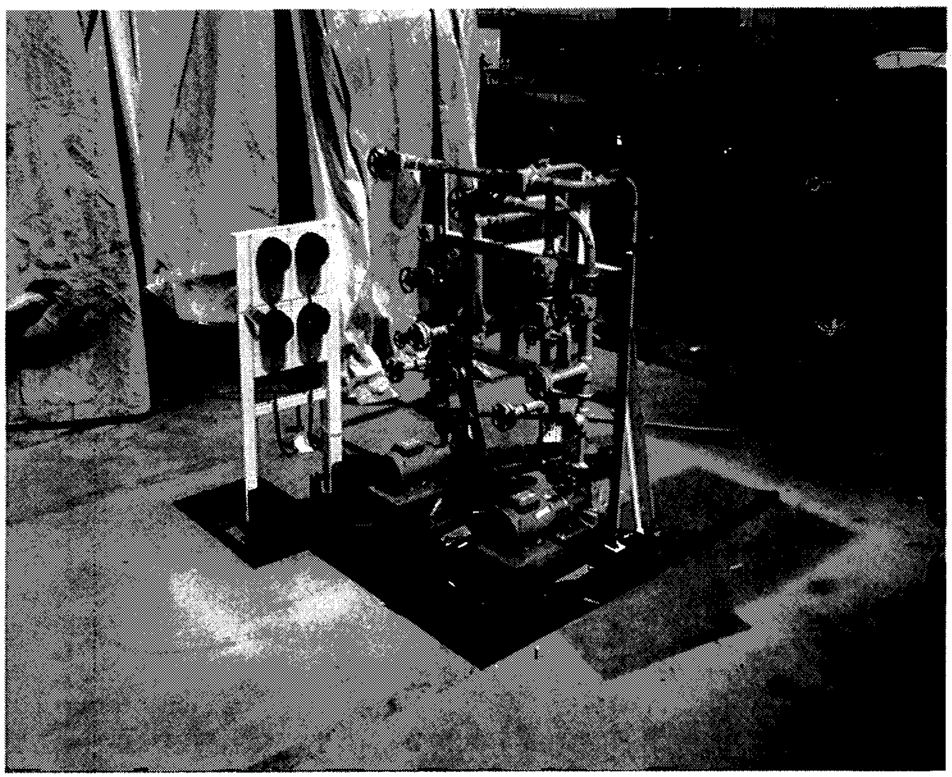


Unit Assembly

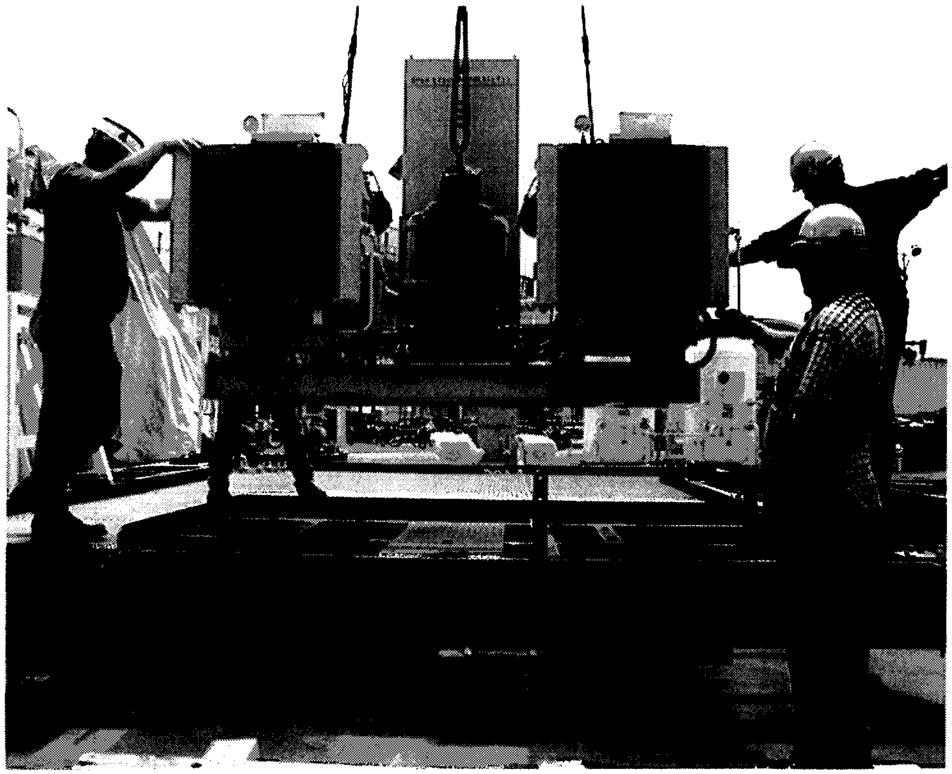


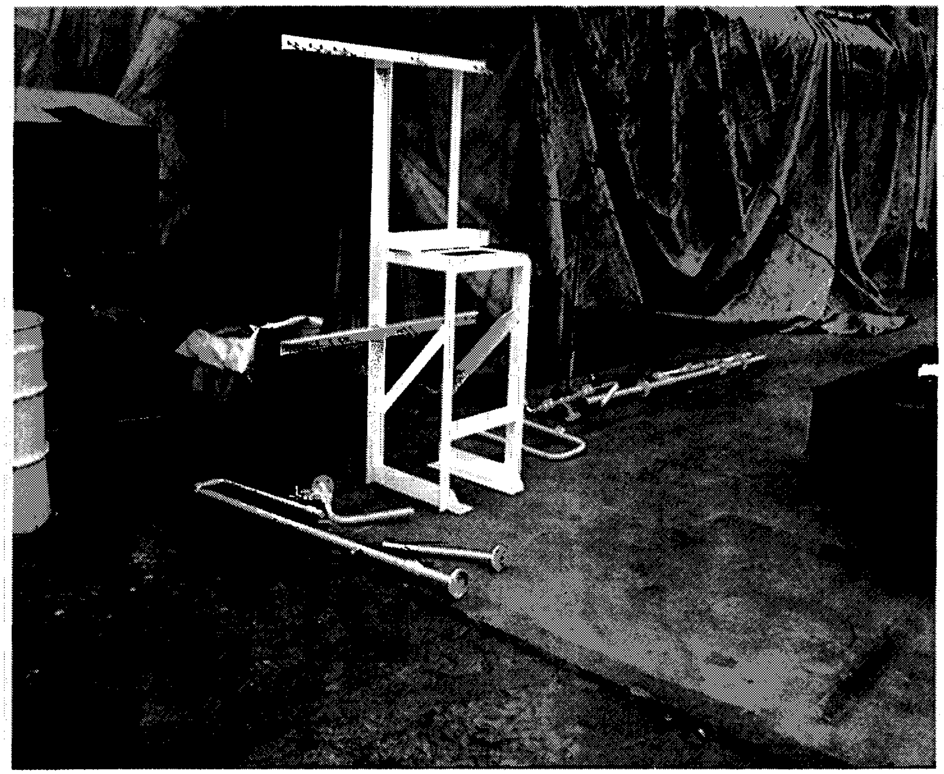
Ship Service Diesel
Generator, Lube Oil
Transfer Unit Assembly

Sub Assembly Installation



Sub Assembly Installation





Questions ?

NATIONAL STEEL & SHIPBUILDING COMPANY

TO: Distribution **DATE:** December 3, 1998

FROM: Rich Burns, ext. 8616 MS-43

SUBJECT: NSRP Project 8-98-2, Process Modeling To Improve Productivity Of On-Board And On-Block Outfitting

Enclosures:

1) Project Organizational Chart
2) Task Responsibility Table
3) Point of Contact Table
4) Project Technical Proposal
5) Project Detail Schedule

NASSCO has been awarded NSRP Project 8-98-2, entitled "Process Modeling to Improve Productivity of On-Board and On-Block Outfitting"

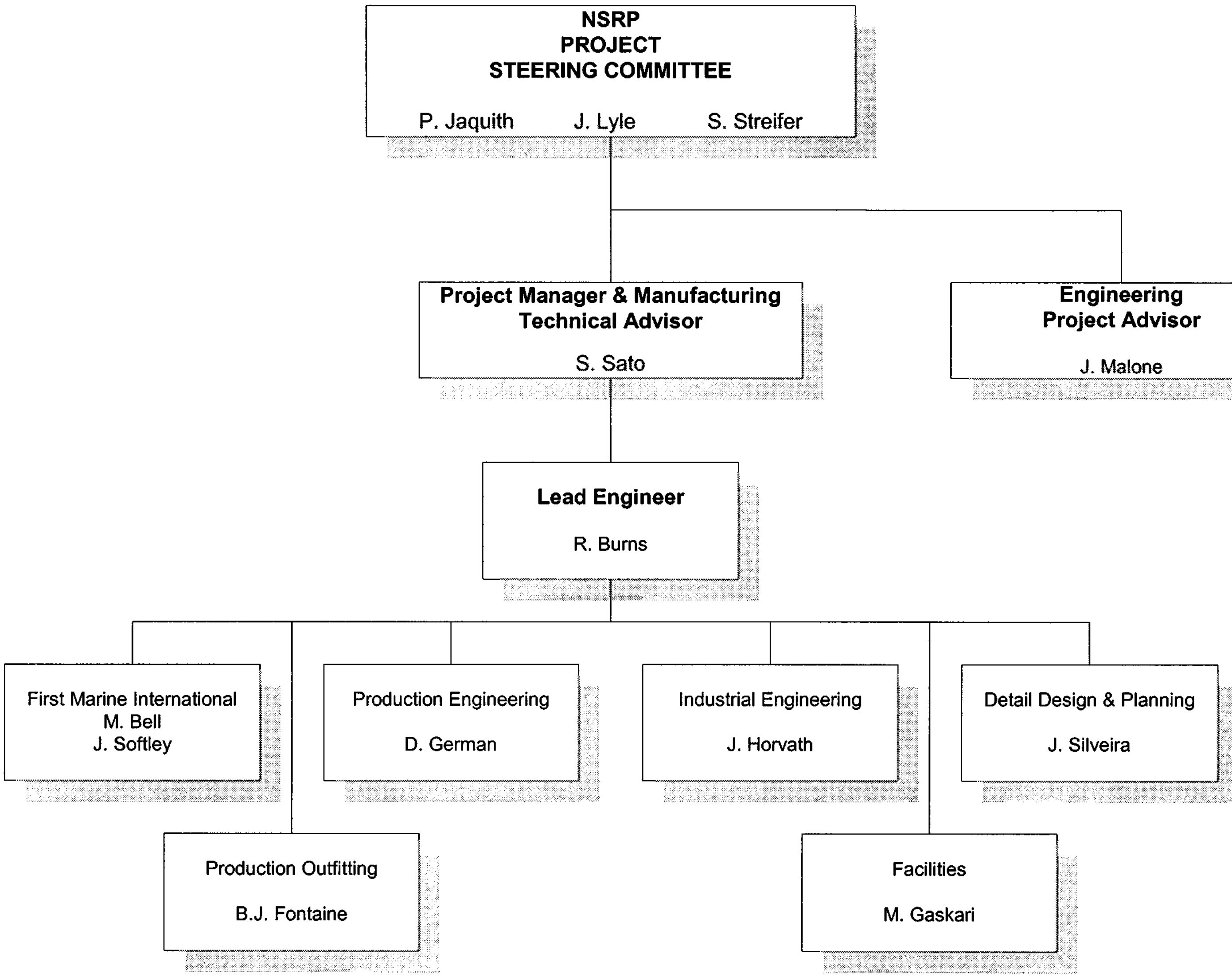
The enclosed documents are submitted for your information.

Enclosure 4 is the original project technical proposal that has been approved and funded by NSRP.

Enclosures 1 through 3 and 5 have been updated or created since project approval to facilitate project completion and understanding of individual roles and responsibilities. Please review these enclosures and provide comments to me by 12/11/98 so we may initiate project activities on 12-14-98.

NSRP 8-98-2 Process Modeling to Improve Productivity of On-Board and On-Block Outfitting

Project Organization



NSRP 8-98-2
PROCESS MODELING TO IMPROVE PRODUCTIVITY OF ON-BOARD AND ON-BLOCK OUTFITTING

TASK RESPONSIBILITY TABLE

Task Number & Description	NASSCO				First Marine International
	Production Engineering	Industrial Engineering	Machinery Design	Other	
1 Establish Shipyard Process Improvement Team	Lead	Review	Review	Review	Review
2 Document Current Production Process Activities	Lead	Assist	Assist	Assist	Review
3 Document World-Class Production Process Activities	Assist	Review	Review	Review	Lead
4 Perform Comparative Analysis	Assist	Assist	Assist	Review	Lead
5 Define Generic Outfit Process Model	Lead	Assist	Review	Assist	Assist
6 Develop Shipyard Specific Outfit Process Model	Assist	Review	Lead	Review	Assist
7 Implement Improved Outfit Process Model	Assist	Review	Lead	Assist	Assist
8 Perform Business Assessment	Lead	Assist	Assist	Assist	Assist
9 Final Report and Industry Workshop	Lead	Review	Assist	Review	Assist

Notes: - "Other" participants include Planning, Production, Facilities, and Cost Engineering.

NSRP 8-98-2
PROCESS MODELING TO IMPROVE PRODUCTIVITY OF ON-BOARD AND ON-BLOCK OUTFITTING

TASK RESPONSIBILITY TABLE

- Production Engineering will take the lead in compiling the project data for submittal of deliverables.

C:\WINNT\Profiles\$42116\Desktop\NSRP 8-98-2\Responsibility Table.doc

Enclosure (2)

NSRP 8-98-2
PROCESS MODELING TO IMPROVE PRODUCTIVITY OF ON-BOARD AND ON-BLOCK OUTFITTING

POINT OF CONTACT TABLE

NAME	ORGANIZATION	PHONE	E-MAIL	FAX	M S	NOTES
Bell, Malcolm	First Marine International	011-356-371911	malcolmbellfmi@compuserve.com	011-356-371911		# in Malta (ext.8616 @ NASSCO)
Burns, Rich	NASSCO Production Eng	(619) 544-8616	rburns@nassco.com	(619) 544-8448	43	
Craggs, John	First Marine International	011-44-171-408-1067	106224.520@compuserve.com	011-44-171-629-6941		
Fontaine, B.J.	NASSCO Production	(619) 544-3660	bfontain@nassco.com	(619) 544-3526	07	
Gaskari, M.	NASSCO Facilities	(619) 544-3447	mgaskari@nassco.com	(619) 544-8410	04-A	
German, Dave	NASSCO Production Eng	(619) 544-8616	dgerman@nassco.com	(619) 544-8448	43	
Horvath, John	NASSCO Industrial Eng	(619) 544-8843	jhorvath@nassco.com	(619) 544-3526	48	
Jaquith, Pete	NASSCO Production Eng	(619) 544-3500	pjaquith@nassco.com	(619) 544-8448	43	
Lyle, John	NASSCO Production	(619) 544-3500	jlyle@nassco.com	(619) 544-3526	07	
Malone, John	NASSCO Adv Programs	(619) 544-8694	jmalone@nassco.com	(619) 544-3663	05-D	
Sato, Shuji	NASSCO Production Eng	(619) 744-1066	ssato@nassco.com	(619) 544-8448	43	
Silveira, John	NASSCO Mach Design	(619) 544-7740	jsilveir@nassco.com	(619) 544-7660	05-H	
Softley, John	First Marine International	011-44-191-261-4772	JohnSoftley@compuserve.com	011-44-191-261-4772		# in Newcastle (ext.8616 @ NASSCO)
Streifer, Steve	NASSCO Engineering	(619) 544-8841	sstreife@nassco.com	(619) 544-3663	05-C	

TECHNICAL PROPOSAL

National Shipbuilding Research Program (NSRP)

PROCESS MODELING TO IMPROVE PRODUCTIVITY OF ON-BOARD AND ON-BLOCK OUTFITTING

Submitted in Response to Panel SP-8, Industrial Engineering
Abstract 8-98-2 and 8-97-3
by

NASSCO
National Steel and Shipbuilding Company
P.O. Box 85278
San Diego, CA 92186-5278

In Consortium With
First Marine International LTD.; 58 St. James Street, London SW1A 1LD, England

Signed:

____
Peter E. Jaquith
Director, Production Engineering

Table of Contents

Section 1: EXECUTIVE SUMMARY

1.1 Introduction

NASSCO has successfully planned and executed numerous projects directed toward profitable competition in the commercial, international shipbuilding marketplace. Among these has been the common goal of implementing outfit design and manufacturing processes that will result in performance improvements necessary to first equal, and then surpass world-class competition.

Outfit projects have focused on key improvement strategies in all shipbuilding process areas. Where these principles have been applied, improvements have been dramatic. Most of the projects completed have been broadly-based, focusing on overall development of standard products and processes. Further emphasis on these, on manufacturing processes, work station definition, and multi-trade environments are the logical next steps to process competitiveness.

NASSCO has evaluated the previously developed NSRP Project Abstract 8-97-3 that has been combined with project abstract 8-98-2, and believes project "best value" will be achieved by focusing this project on implementation of improved on-block and on-board outfitting processes based upon

world-class practices including the application of multi-craft work teams. NASSCO notes that the scope of this project is related to both on-block and on-board processes. Thus, NASSCO proposes to re-title, and provide the technical approach for, "Process Modeling to Improve Productivity of On-Board and on-Block Outfitting."

1.2 Project Objectives

The primary objective of this NSRP project is to establish a world-class on-block and on-board process by which interim product family components are competitively assembled and installed in a multi-trade work environment for new construction shipbuilding.

Project focus areas are:

-Processes improvement in areas that assemble interim product structures.

-Processes improvement in the On-block and On-board areas that consume interim product structures.

This will be accomplished by:

-Documenting current domestic production process activities related to on-block and on-board outfitting.

-Documenting world-class international processes observed and documented during recent visits to world-class Asian and European shipyards, and related U.S. assembly industries.

-Comparative analysis of Domestic and International processes.

-Definition of a generic outfit product model including sequence of assembly and installation.

-Development and implementation of a shipyard specific outfit process model.

Section 2: BODY OF PROPOSAL

2.1 Technical Approach

NASSCO plans a 18-month project that will culminate in documentation of a specific interim product structure, assembly and installation process, demonstrated implementation of the process on a new building program (upon contract award), industry presentation, and workshop.

NASSCO has been instrumental in accomplishment of numerous NSRP, MTSL, MARITECH, internal process improvement, and domestic and international industry benchmarking projects that have a direct relationship to the proposed NSRP "Process Modeling to Improve Productivity of On-Board and on-Block Outfitting" project.

In support of this project, NASSCO will leverage the strengths of its project partners, and exploit the combined Project Team knowledge obtained through accomplishment of these internal and external projects to plan and accomplish a synergistic series of project tasks leading to achievement of project goals.

Examples of outfit design and manufacturing, domestic, and international benchmarking projects that will enhance the proposed project are listed below :

Related Outfit Design and Manufacturing Projects; (Completed and/or On-going)

-Multi-skilled Work Teams (NSRP 5-90-1) 1992 and 1993.

-Cold Pre-outfit and Outfit Assembly Construction Standards (Internal) 1994 and 1995.

-Design & Construction of Machinery Units for Sealift Ro/Ro's (Internal) 1994 and 1995.

-Parametric Standard Machinery Unit System (Midterm Sealift Contract N00140-94-D-BC08) 1995 and 1996.

-Build Strategy Development for recent programs (Internal) 1996 to present.

-Design for Production Manual (Internal/NSRP 4-95-1) 1997 to present.

-Standard Commercial Ship Test Plan (NSRP 6-95-1) 1997 to present.

-Standard Foundation & Hanger Systems (NSRP 6-95-2) 1997 to present.

-MARITECH Ship Factory Transformation Project (DTMA91-97-H-00003) 1997 to present.

Domestic and International Benchmarking Projects;

-Large and medium sized European shipyards including Odense Steel Shipyard, Kvaerner ASA, Meyer Werft, Fincantieri Monfalcone, and Van Der Giessen.

-Large and medium sized Asian shipyards including KHI's Kobe and Sakaide, IHI's Aioi and Kure, Hitachi, and Samsung.

-KHI Technology Transfer Program in place 1994, to present.

-Raytheon Engineers & Constructors, Power & Petrochemical plants in Stockton, CA and La Barge, WY.

-GM Auto Assembly in Lansing, MI.

-Boeing Commercial Aircraft in Seattle, WA.

NASSCO=s technical approach is illustrated by Figure 1 "Template for Process Modeling to Improve Productivity of On-Board and on-Block Outfitting." Project tasks are further described below:

2.2.1 Task-1: Establish Shipyard Process Improvement Team

NASSCO has selected the key Shipyard Process Improvement Team members that will support and accomplish the proposed NSRP "Process Modeling to Improve Productivity of On-Board and On-Block Outfitting" project. These personnel have been selected based on their familiarity with NASSCO's current outfitting initiatives, strategies and goals; NSRP project management experience,

and previously demonstrated performance.

Upon project award the assigned personnel will assemble the balance of the Project Team, conduct project reviews and assignments, and initiate task accomplishment. The completed project staff will be comprised of a core of experienced project management personnel supported by an mix of Production Outfitting, Production Engineering, Industrial Engineering, Facilities, Detail Design and Planning personnel appropriate to individual task accomplishment.

Project Team organization and personnel are further discussed in Paragraphs 2.5.2 and 2.6 respectively.

DELIVERABLE:

Project Organization;	-Updated and completed Organization Chart
	-List of names and points of contact

2.2.2 Task-2: Document Current Production Process Activities

NASSCO area of project focus will be the On-Block and On-Board processes that assemble and install NASSCO's outfit interim product structure.

The Project Team will document the hierarchy of components that are assembled to create outfitting sub-assemblies, assemblies, units, and outfitted blocks comprising the outfit interim product structure. The Project Team will also document the process by which the outfit interim product structure is assembled and installed, outfit material flow, and outfit workstation capabilities. In support of comprehensive product and process documentation, the team will integrate producibility attributes and manufacturing processes developed during previously conducted, or on-going projects.

DELIVERABLE:

Interim Technical Report;	-Documentation of current outfit interim product structure
	-Documentation of current outfit assembly process
	-Documentation of current outfit installation process
	-Documentation of current outfit material flow
	-Documentation of current workstation capabilities

2.2.3 Task-3: Document World-Class Production Process Activities

The Project Team will document world-class on-block and on-board processes relative to outfit interim product structure assembly and installation as observed in Asian and European shipyards, and U.S. assembly industries.

Documentation will include a composite definition of the interim product structure, assembly, and installation processes as observed during benchmarking processes conducted in the shipyards listed on Paragraph 2.1. In addition, the Project Team will integrate the "best practices" observed in other domestic world-class manufacturing organizations as applicable to the shipbuilding process.

DELIVERABLE:

Interim Technical Report;

-Documentation of World-class outfit interim product structure

-Documentation of World-class outfit assembly process

-Documentation of World-class installation process

2.2.4 Task-4: Perform Comparative Analysis

The Project Team will perform a comparative analysis of NASSCO's current, and world-class outfit interim product structure assembly and installation processes. The analysis will be performed by identification, and performance measurement of the product structures, production methodologies, and processes used to assemble and install the product structure.

The Project Team will collate outfitting interim product structure data, work breakdown structure, product category organization and rationale, standardization methodologies, producibility initiatives, production performance goals, facility data, workcenter layout, workcenter core competencies, material flow, and other manufacturing product and process data necessary to develop the analysis.

The analysis will be conducted for a range of outfitting part and subassembly product types. It will integrate the findings recommendations and implemented process improvements resulting from other completed and/or on-going NSRP, MTSL and MARITECH projects.

Additionally, the analysis will include a list of specific recommendations that may be translated into a set of implementable actions.

DELIVERABLE:

Interim Technical Report;

-Comparative analysis of NASSCO current, and World-class outfit interim product structure, and installation processes

-Recommendations that may be translated into a set of implementable actions

2.2.5 Task-5: Define Generic Outfit Process Model

The Project Team will utilize the data developed from Project Tasks 2, 3, and 4 to develop a generic outfit assembly and installation process model. The generic model will illustrate the selected outfit

interim product structure, assembly and installation process.

The generic model will be designed to support analysis of identified producibility attributes and will provide the baseline by which product model improvements may be measured in support of Project Tasks 6 and 7. Additionally and significantly, the generic model will also be available for use by other shipyards as a reference standard for development of other facility-specific outfit process improvements.

DELIVERABLE:

Interim Technical Report; -A generic outfit interim product structure, assembly and installation process model for new construction shipbuilding

2.2.6 Task-6: Develop Shipyard Specific Outfit Process Model

The Project Team will utilize the data developed from Project Tasks 2, 3, 4 and 5 to develop a shipyard specific outfit product model. The specific model will illustrate the selected outfit interim product structure, assembly and installation processes that: a) optimize identified world-class practices, b) may be constructed within, or in support of the current NASSCO facility, or c) may be constructed within, or in support of a proposed future NASSCO facility.

The specific model will include an illustrative description of the selected outfit interim product structure, description of optimum workstation characteristics, workflow, and process lane methodologies used to assemble, and install the selected family of outfitting products, including Machinery, Pipe, Vent, Metal Outfit, and Electrical product categories.

The specific model will result in identification of optimum outfitting interim product structures and manufacturing process drivers. Additionally, training required to support this outfit model will be identified in order to ensure necessary production, production support, and management skills.

DELIVERABLE:

Interim Technical Report; -A shipyard (NASSCO) specific outfit process model including the outfit interim product structure, assembly and installation process, material flow analysis and workstation characteristics

2.2.7 Task-7: Implement Improved Outfit Process Model

During the comparative analysis of Project Task 4, recommendations will have been documented.

The recommendations will be formatted to support translation into a set of implementable actions. When approved by the Steering Committee, and upon award of a new ship building program at NASSCO, Project Team members will initiate the implementation process.

The implementation process will require an implementation plan. The plan will be developed by the Project Team in support of approved implementation recommendations. The Project Team will coordinate and monitor the implementation process in accordance with the plan, and will provide regular Steering Committee reports. The Steering Committee will ensure that Project Team efforts are facilitated by adequate infrastructural support.

DELIVERABLE:

Interim Technical Report; -Implementation plan developed specifically for approved recommendations, in support of an awarded new building contract

-Initial implementation findings

2.2.8 Task-8: Perform Business Assessment

The Project Team will develop a business assessment of the improved outfit process model. The assessment will collate all product cost and quality data necessary to develop a comprehensive business analysis. The assessment will consider manufacturing and assembly processes, workflow and process lane approaches, identification and evaluation of individual workstation processes, machinery, and tooling required to assemble and install the selected interim product structure in a multi-trade environment. Critical reviews will include workpackage Ashop floor≅ orientation to specific workstations, applicability to appropriate stages of construction, and optimization of facility use.

DELIVERABLE:

Interim Technical Report; -Business Assessment of NASSCO improved outfit interim product structure

2.2.9 Task-9: Final Report and Industry Workshop

NASSCO will develop a draft final report for NSRP SP-8 Panel review and comment. The draft report will be submitted at the conclusion of project tasks through 2.2.8. The draft report will principally consist of a compilation of the interim reports submitted during the course of the project. Additional reporting data will be included to the extent that updated information applies.

Upon NSRP SP-8 Panel comment and approval, the Project Team will incorporate NSRP comments, complete, and submit the final report.

NASSCO will also prepare and conduct an Industry Workshop that demonstrates the concepts and findings of the project. The workshop will be prepared for conduct at the annual Ship Production Symposium. The workshop format will be developed based upon previous workshops conducted by NASSCO.

DELIVERABLEs:

Draft Final Report;	-Compilation of the interim reports and other relevant project data and findings
Final Report;	-Final report including appropriate NSRP comments
Industry Workshop;	-Industry workshop at the annual Ship Production Symposium

2.3 Reports

Quarterly reports will be presented at the regular NSRP SP-8 Panel meetings. As may be convenient, the panel meetings and project review will be conducted on-site at NASSCO. Key project members will be present and/or will participate. Progress of each task and sub-task will be assessed. NASSCO will provide regular reports of progress and total costs to the NSRP SP-8 Panel. Status reports will include a billing summary based on progress achieved, and narrative description of progress made since the last reporting period.

2.4 Benefits to the Industry

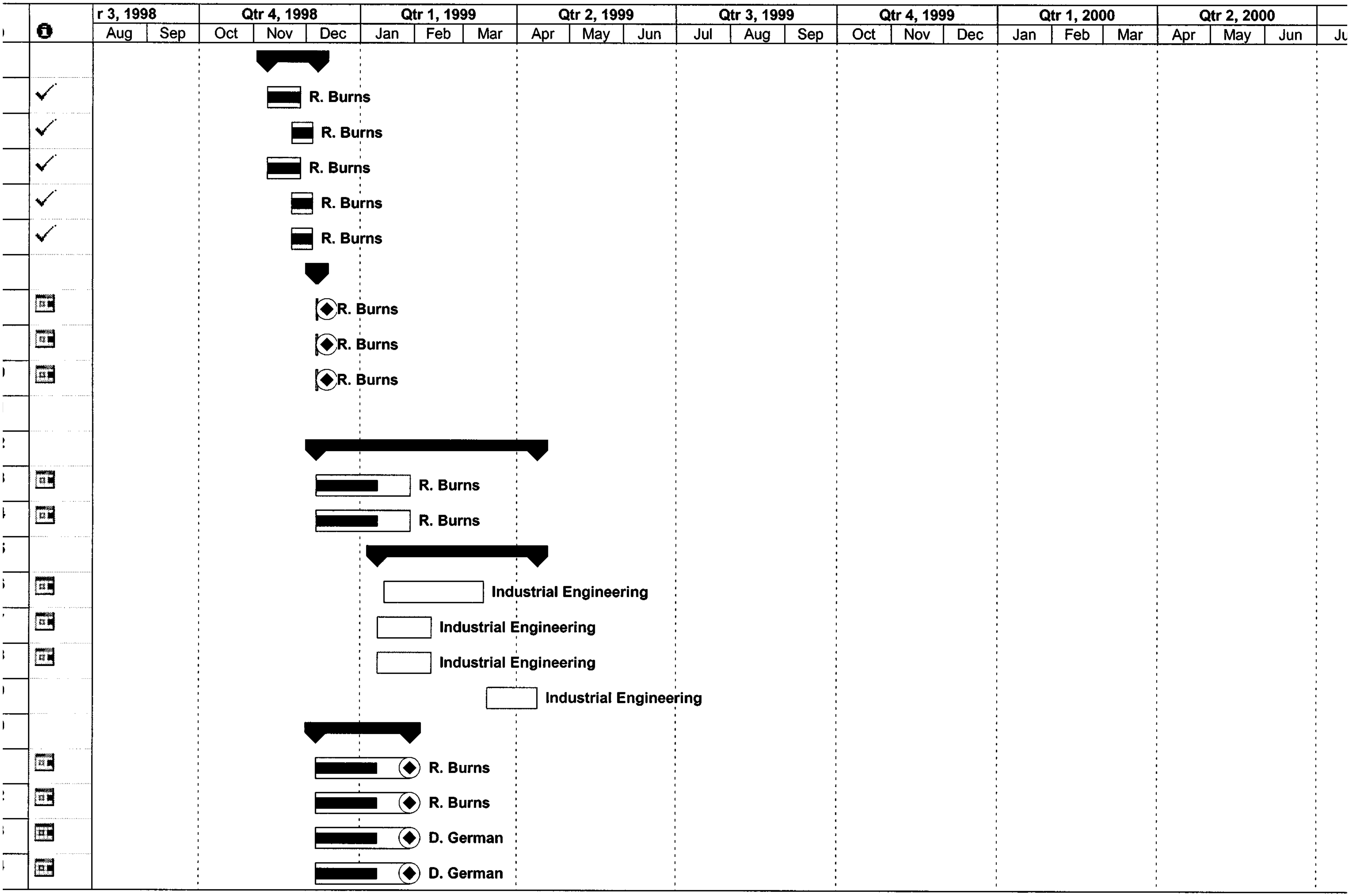
This NSRP project is intended to document a world-class process by which interim product family components are competitively assembled and installed in a multi-trade work environment. The primary benefit of this approach is validation of an outfit interim product assembly and installation methodology via application on an actual new building contract. It is anticipated that the approach will support significant cycle time and cost reduction throughout on-block and on-board production phases which is critical for U.S. shipyard re-entry into the commercial shipbuilding market. Additionally, the proposed project will result in the following listed benefits to the shipbuilding industry:

- Documentation of NASSCO's current outfit assembly and installation processes
- Documentation of a generic world-class outfit assembly and installation process
- Documentation of a shipyard specific application
- Business assessment of the improvement initiative
- Applicability to both commercial and Naval programs

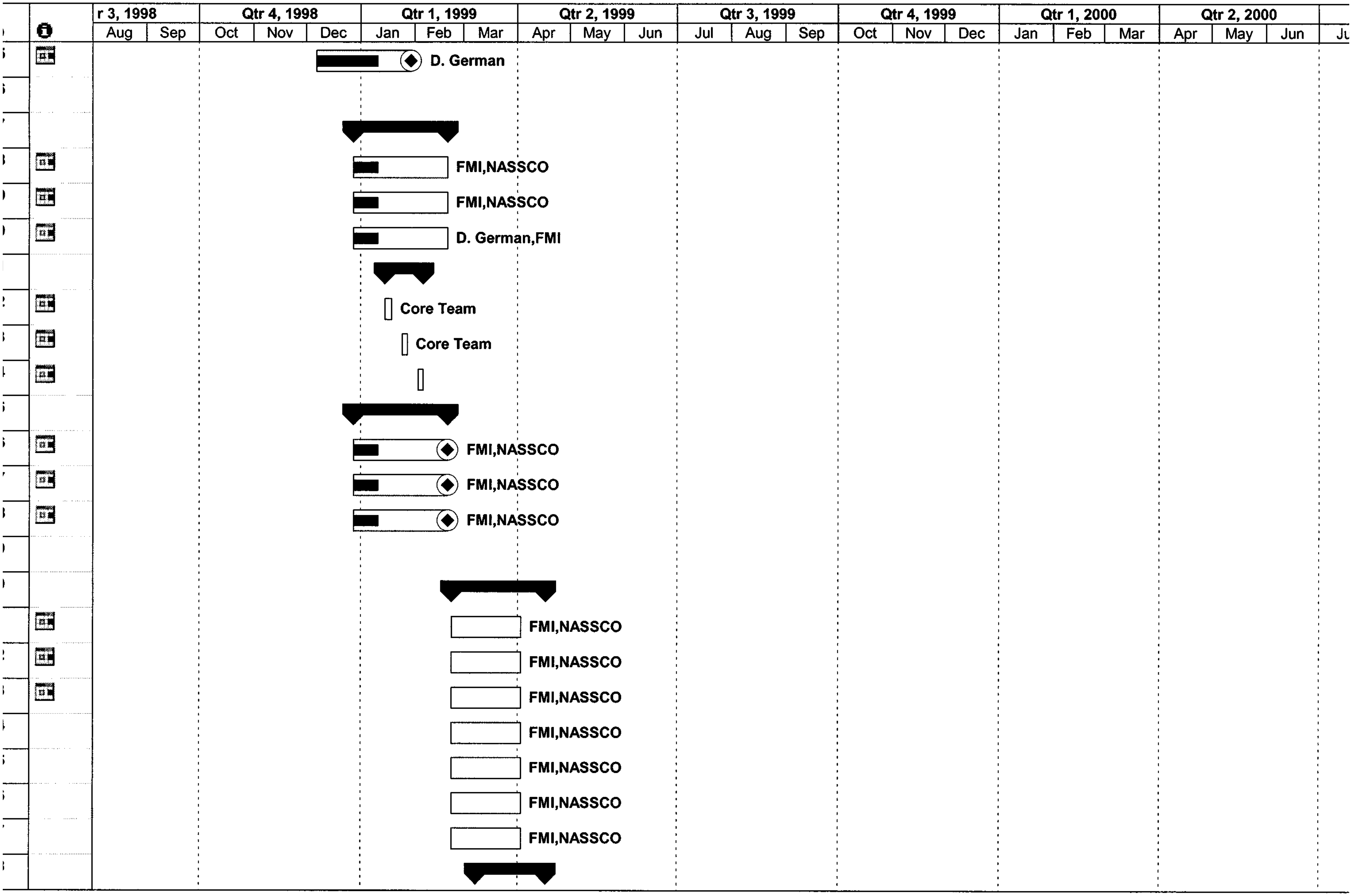
2.5 Management Plan

NASSCO will be the prime contractor and team leader for this project. NASSCO will utilize a Steering Committee comprised of in-house experts from each of the functional areas involved, and will also include representatives from First Marine International, (FMI). The purpose of the Steering Committee is to address strategic issues and to ensure all project tasking is proceeding in accordance with the plan.

Process Modeling to Improve On-Board and On-Block Outfitting (NSRP 8-98-2 && 8-97-3)



Process Modeling to Improve On-Board
and On-Block Outfitting (NSRP 8-98-2 && 8-97-3)



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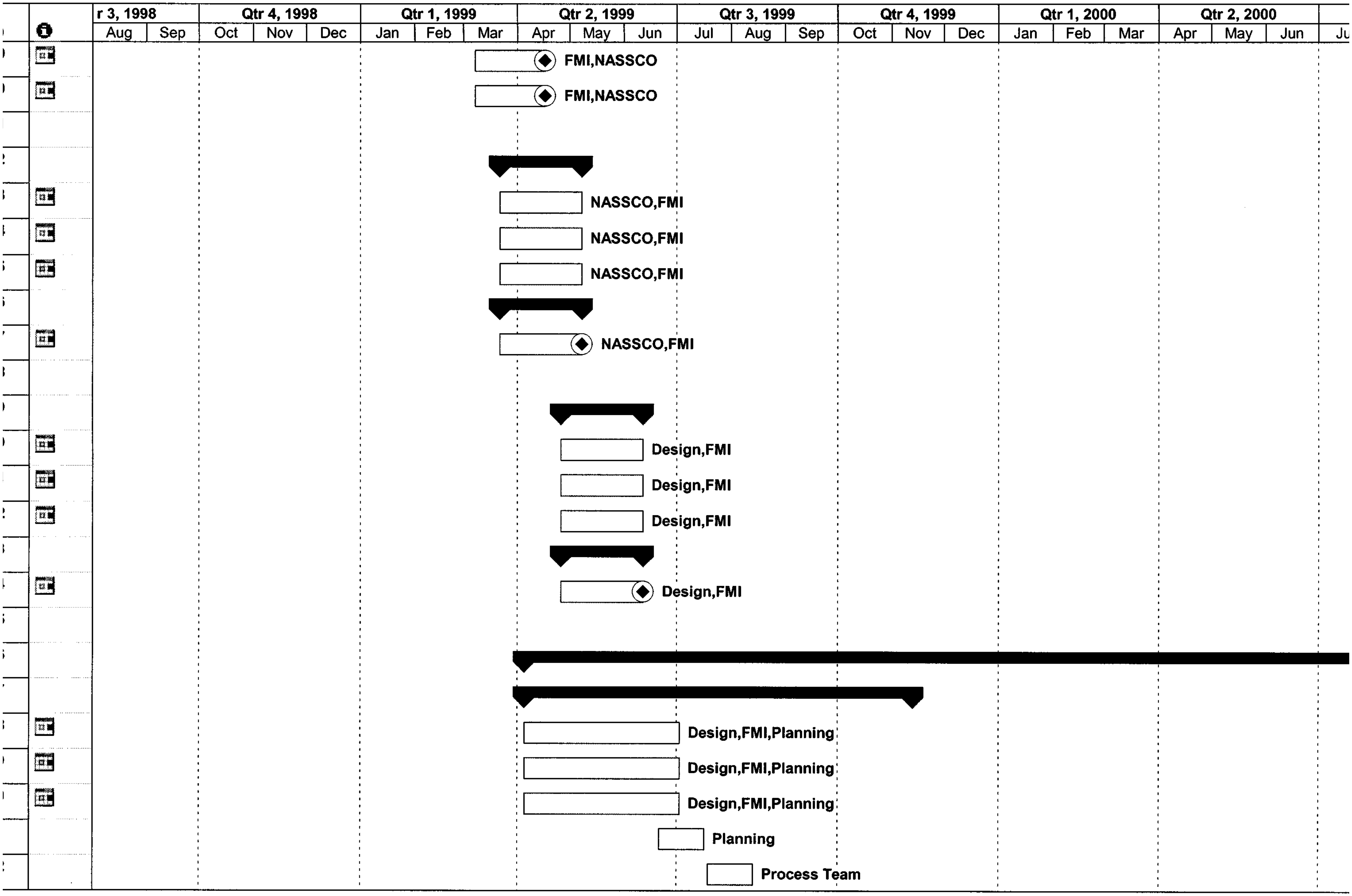

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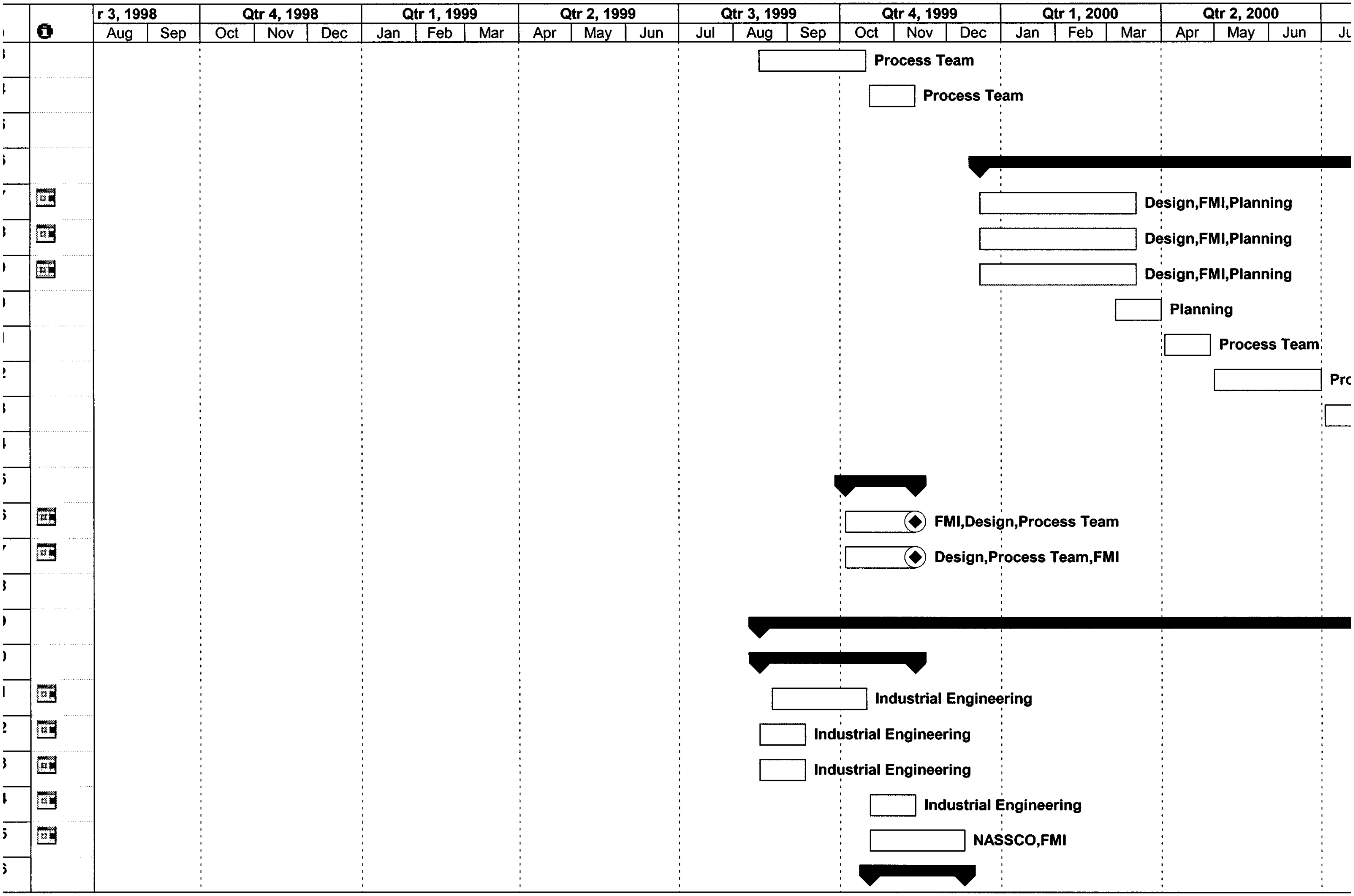
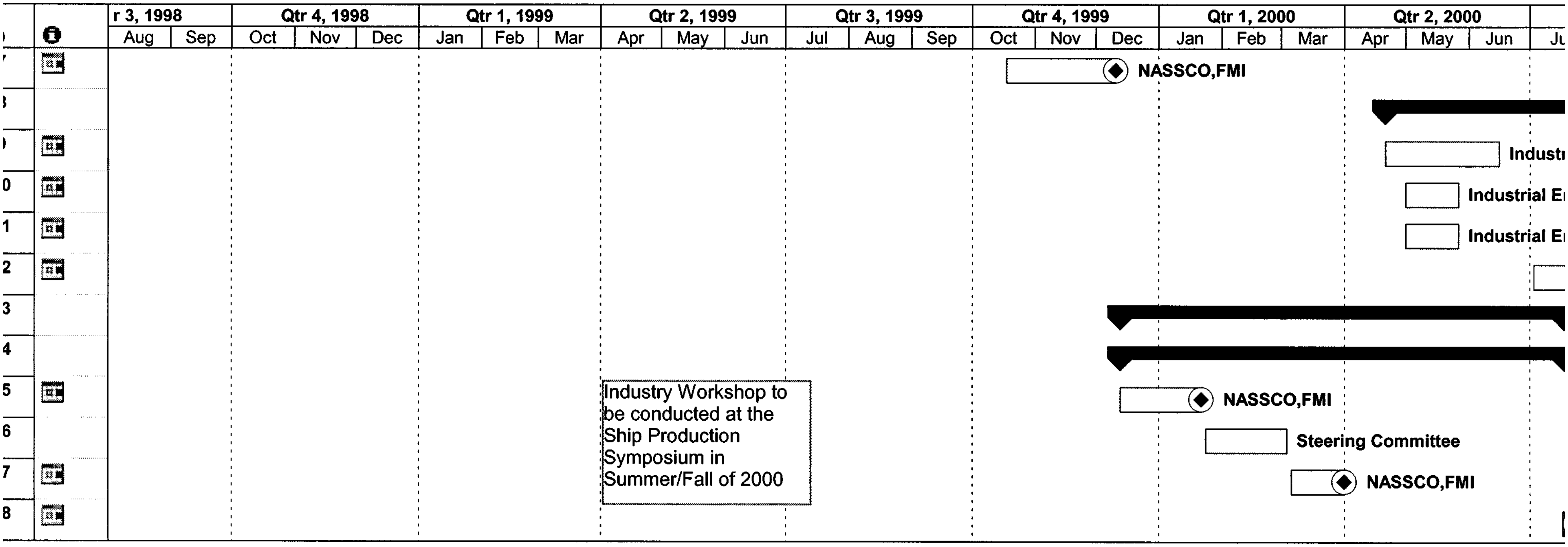
and On-Block Outfitting (NSRP 8-98-2 && 8-97-3)



Process Modeling to Improve On-Board and On-Block Outfitting (NSRP 8-98-2 && 8-97-3)



NATIONAL STEEL AND SHIPBUILDING COMPANY

NSRP PROJECT 8-98-2

Process Modeling to Improve Productivity of On-Board and On-Block Outfitting

Task 2 Deliverable

Document Current Production Process Activities

FIRST MARINE INTERNATIONAL LIMITED

February 1999

Document Current Production Process Activities

CONTENTS **Page**

1 Introduction

NASSCO has successfully planned and executed numerous projects directed toward profitable competition in the commercial, international shipbuilding marketplace. These projects have shared the common goal of implementing outfit design and manufacturing processes that will result in performance improvements necessary to first equal, and then surpass world-class competition.

Outfit projects have focused on key improvement strategies in all shipbuilding process areas. Where these principles have been applied, improvements have been dramatic. Most of the projects completed have been broadly-based, focusing on overall development of standard products and processes. Further emphasis on these standards, including manufacturing processes, work station definition, and multi-trade environments are the logical next steps towards process competitiveness.

One of the primary objectives of the outfit analysis process is to move outfit assembly work to the most cost effective stage in the build cycle. The cost savings can be quite dramatic if outfit is integrated with earlier stages of ship construction as illustrated in Figure 1. This shows the cost benefits of integrating steel and outfit at the most effective stage in the assembly and construction process. It has been proven that integrating outfitting at the most effective time in the assembly process can reduce overall outfitting costs by over 50% compared with traditional zone outfitting.

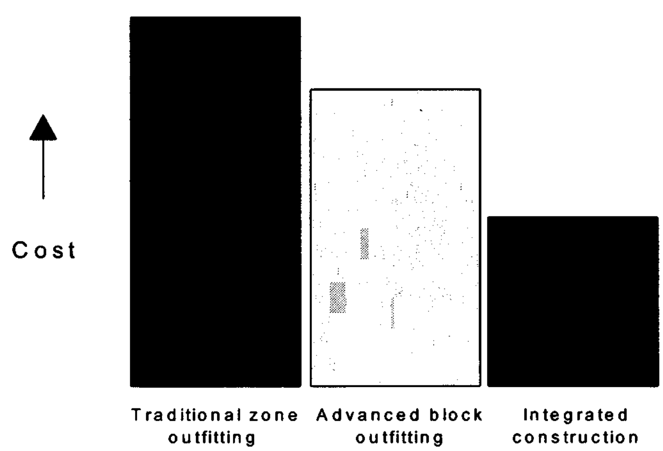


Figure 1
Effect of outfitting methodologies

It should be noted that transferring of outfit items to earlier assembly stages must be tempered with the understanding that it is not effective to move all items to the earliest assembly stages. There is an optimum time for integrating each product type which considers the physical location in the ship. Moving to the earliest possible stage can sometimes result in rework and should be avoided. The diagram in Figure 2 shows the typical oufitting stages for each type of product.

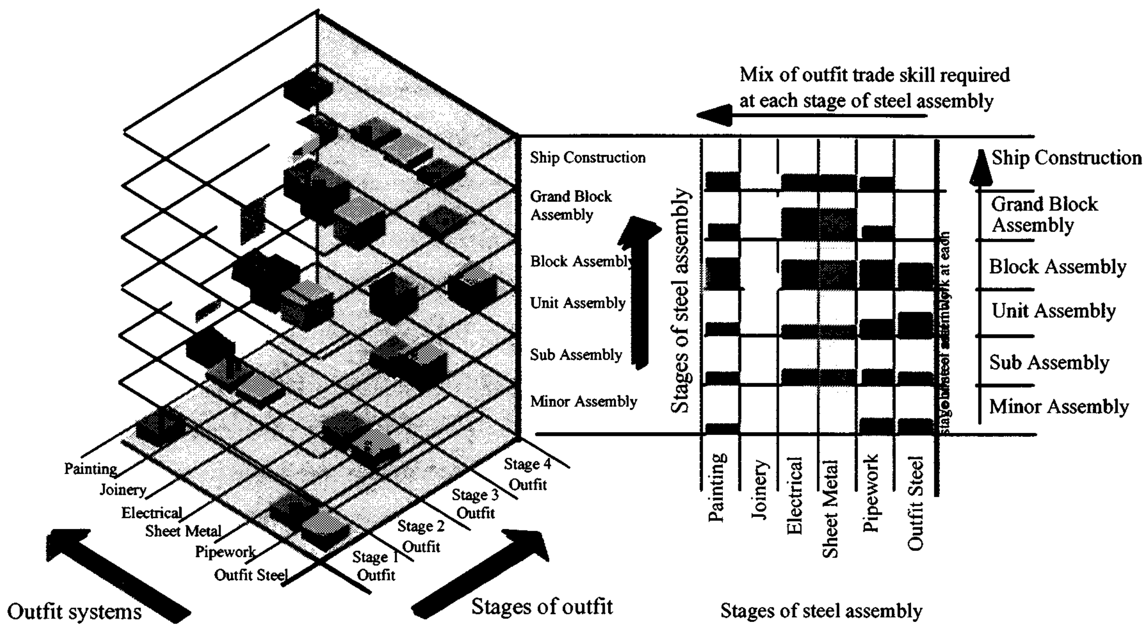


Figure 2
Modern outfitting methodology

It is equally important to decouple the assembly of outfit items from the steel block assembly stage as much as possible otherwise the installation of large numbers of individual outfit parts adversly impacts the steelwork facility utilization. Developing a range of outfit interim products such as multi-trade assemblies that combine the distributive systems and enables the shipyard to minimize the outfit duration at the steel block stage while simultaneously reducing the cost of assembling outfit items by using dedicated outfit assembly workstations.

The processes described in the coming project deliverables will enable NASSCO to develop outfitting in a structured manner similar to that for structural steelwork by developing an approach for the consistent definition of outfit interim products.

The area that this project will focus on will be in both the On-Block and On-Board areas. The project will be primarily concerned with the processes that assemble and install NASSCO's outfit interim products. However, in order to provide a complete understanding of the project and an integrated project approach, both the current and proposed outfit interim product structure will be identified across all stages of construction.

2 Objective

The objective of the Project Team will be to document the hierarchy of components that are assembled to create outfitting sub-assemblies, assemblies, units, and outfitted blocks comprising the outfit interim product structure. The Project Team will also document the process by which the outfit interim product structure is assembled and installed, outfit material flow, and outfit workstation capabilities. This documentation will primarily focus on the On-Block and On-Board areas. In support of comprehensive product and process documentation, the team will integrate producibility attributes and manufacturing processes developed during previously conducted, and/or on-going projects. This deliverable will provide the following to be used for evaluation and to make recommendations in the later project deliverables:

-Documentation of current outfit interim product structure

-Documentation of current outfit assembly process

-Documentation of current outfit installation process

-Documentation of current on-block and on-board work centers

-Documentation of current outfit material flow

3 Current outfit interim product structure, assembly and installation processes

This section documents the structure of the current outfit interim products. It will assist in identifying the outfit interim products to maximize the use of the assembly facilities. It will also look at the assembly and installation processes related to the current outfit interim products.

The objective of the analysis is to define the types of outfit interim products and to group them into product families by similar production process. The overall sequence of the analysis is shown below.

VESSEL

⇩

OUTFIT PRODUCTION STAGE

⇩

OUTFIT PRODUCT TYPE

⇩

OUTFIT PRODUCT FAMILY

Outfit interim products include those products fabricated in shops, assembled in fixed workstations, and those assembled in transient workstations such as block join-up and zone completion.

The range of steelwork interim products is well documented in other projects. Since steelwork has a fairly limited range of products, it is easy to group them into product families ranging from small piece parts to major block types. However, as outfit has traditionally been seen as a set of small individual items which have generally been fitted at the later stages of the build process there has been little need to group them into product families. This perception has changed with the need to reduce the cost of outfit manufacture and installation.

Two major differences between identifying steelwork interim products and the outfitting equivalents is 1)traditionally outfitting continues long after the steelwork is complete and 2)outfitting is incorporated into the steelwork. The integration of

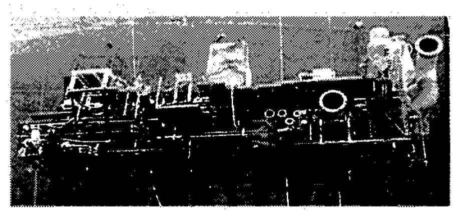
outfitting and steel has resulted in a misdirected approach which attempts to combine steel and outfit into a single interim product structure based on steelwork interim product types alone. In reality, many outfit interim products should be regarded as being independent of the structural constraints and based more on the functional areas where they are located.

During development of SLNC strategies concerted efforts were made to move towards an interim product approach. This was done extremely effectively in some areas such as the lower level engine room, specific machinery areas and uptakes. The majority of the ship, however, was still designed using a traditional outfitting approach.

Typical examples of current outfit assembly interim products are:

- T & S (toilet and shower) modules for accommodation areas,
- Small equipment modules which group pipes, vents and electrical services into common assemblies,

- Machinery modules which combine aspects of the above into an engineering based assembly of framework, equipment and services.



When these outfit products and other outfit parts are integrated into structural steel interim products they form a new integrated interim product based on the steelwork breakdown structure.

Typical examples of current integrated interim products include:

- Minor and sub assemblies e.g. floors and girders with manholes, penetrations, inserts and handholds,
- Main structural panels which include the above together with foundations, backing structure and piping,

- Blocks which may include the full range of outfit interim products.

Similarly, the final assembly of outfit parts into erection join-ups and zones of the vessel should be regarded as a separate set of outfit interim products, based upon stages of completion.

Typical examples of current joint and zone interim products include:

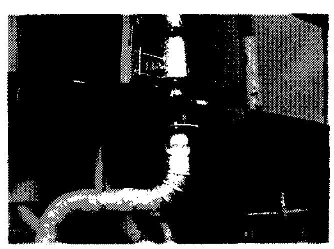
- The structural join-up of block to block or block to ship and the staged completion of the outfit over the joint area.

- The completion of the outfit in individual or groups of compartments, such as open deck areas or zones.

In the case of outfit parts the interim product families are generally categorized by system, for example:

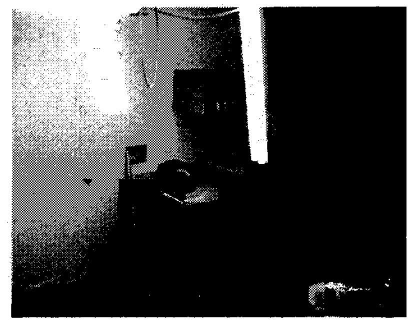
- Pipework families

- Ventilation families

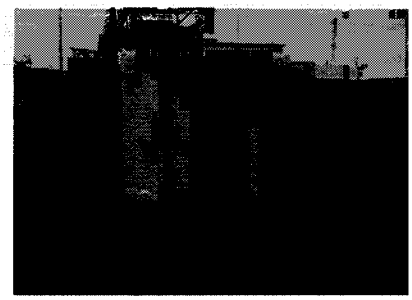


- Foundations including studding, back-up structure etc.

- Metal joiner such as: ceilings, bulkheads & linings, furniture, doors & windows

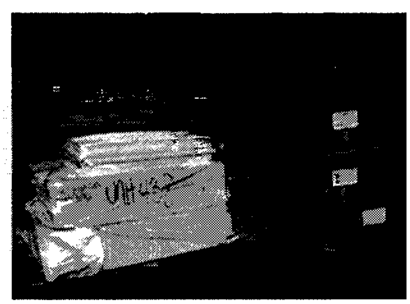



- Electrical, including main and local cabling, main electrical equipment, connectors, connection boxes, light fixtures etc.

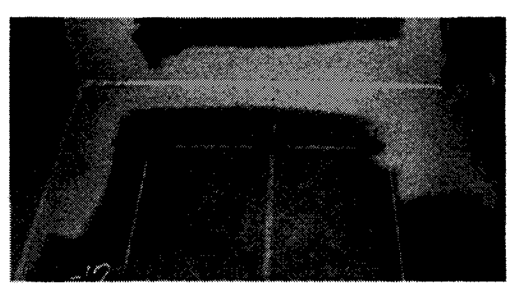



- Main propulsion, auxiliary equipment, deck machinery, gear systems, cargo loading systems, personnel elevator, galley/refrigeration equipment etc.


- Insulation pins, hull board, lagging, insulated pillows etc.

- Painting including mechanical clean/sandblast, primer coats, final coats, anti-fouling etc.



Additional interim product families include

- Deck coverings including screed, carpet/linoleum, terrazzo etc.
- Soft furnishing, including mattresses, bedding, curtains etc.

As part of NASSCO 2000(NASSCO's Vision) and ISO 9001 the company has undertaken a study of all processes involved in the construction of a vessel. The production processes which fabricate and install the product families and outfit interim products are identified in the various NASSCO Quality Procedures Manuals. The single reference which identifies all of these Quality Procedures Manuals is maintained by the Quality Assurance(QA) department. These manuals include the specific shop manuals which fabricate the majority of NASSCO's family of current outfit interim products such as Pipe, Electric, Metal Outfitting and Sheetmetal Shop Manuals. The documentation also includes the Quality Procedures Manuals for the areas that currently combine and consume NASSCO's family of outfit interim products such as On-Block and On-Board. In addition to the Quality Procedures Manuals there are also second tier documentation that further describe production processes such as outfitting product attribute sheets, expert OJT project worksheets and trade performance evaluations.

In order to illustrate and provide a rough quantification of the current outfit interim product structure and process at NASSCO an area of the SLNC was selected and analyzed. This area included several blocks within an auxiliary machinery space. A count for the products was performed at each stage of construction and is contained in Appendix A. The products have been broken down into various product types and families as described previously, these include: piping, ventilation, machinery, metal outfitting, insulation, paint, electrical and joiner.

For each product structure, the count given is in terms of a quantity, unless otherwise specified. For example, for the ventilation product count at the block level, there are nine vent supports, two studs, six rectangular vent pieces, eighteen vent fittings, and forty-seven feet of spiral vent installed at this stage. Spiral vent, unlike rectangular vent, is quantified in units of length, not number or quantity.

The paint product structure breakdown count is unique as compared with the other product breakdowns. For the paint product structure, the total block painting area for the selected analysis is 12,745 square feet, of which 2,549 square feet are

subcontracted to a vendor. At the steel level, all raw steel, plates, and shapes are pre-treated at the prime line. However, not all small parts or minor assemblies are primed or final painted at NASSCO's blast and paint workstation even though, some trade-specific workstations may primer and paint minor assemblies. For example, the sheetmetal shop has its own paint workstation/workcenter. Therefore, for this analysis, the count of parts given is for items that show a paint workcenter in the process routing.

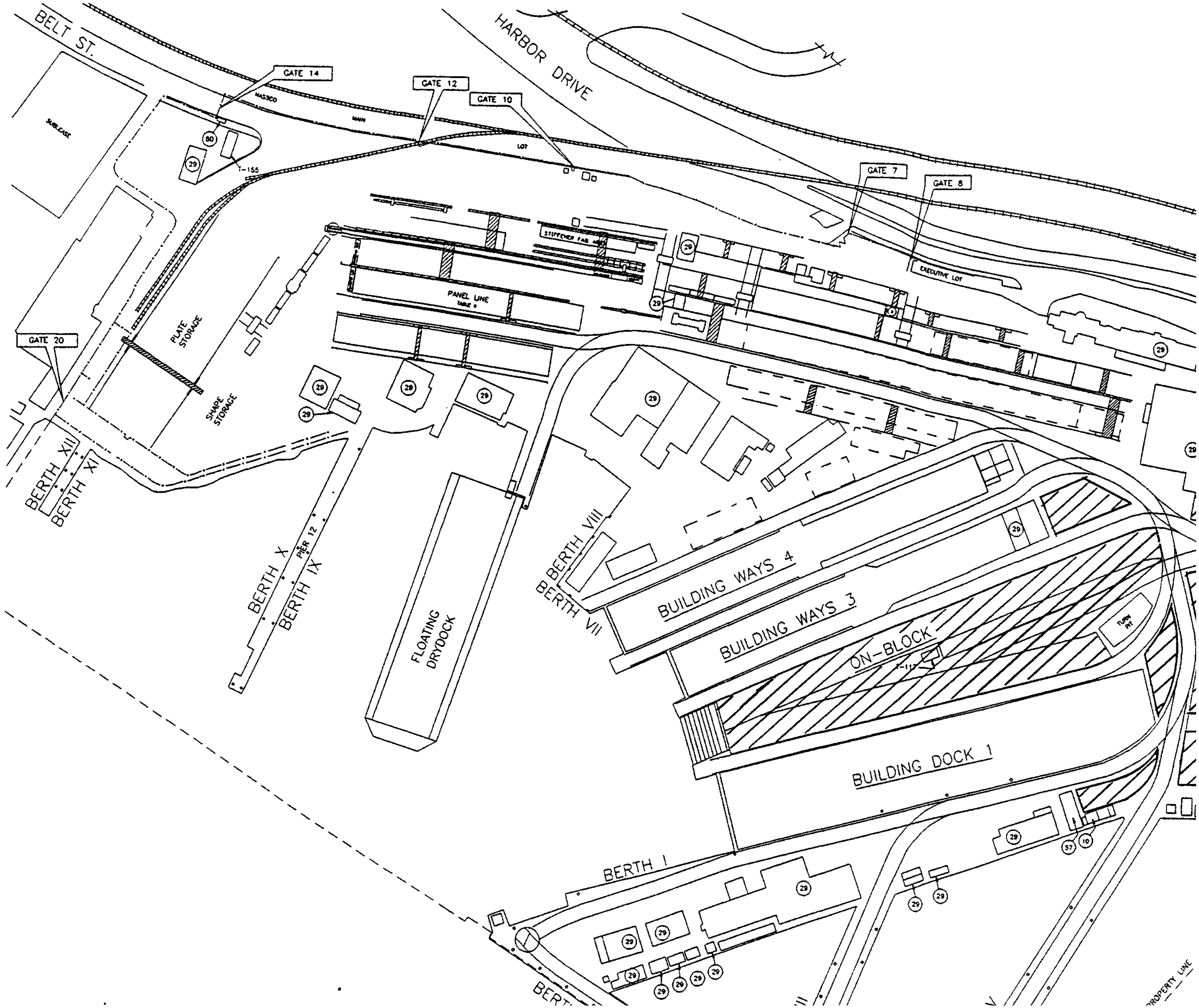
The insulation product breakdown also contains some details which must be addressed. The count was performed for structure or hull insulation (i.e. bulkheads, decks, beams, longitudinals), with the exception of some piping (pipe spools). Lagging is done only after the pipe tests. Fire boundary penetrations (i.e. pipe spools) are also done by insulation, both on board and on block.

The process flow charts shown in Appendix A are not intended to fully quantify the interim products for the SLNC's constructed at NASSCO but to provide a general representation of the current product integration process.

4. Current on-block and on-board work centers

This section will identify the current work centers for On-Block (SOC 5) and On-Board (SOC 6) along with identifying the constraints in which they operate. These areas are currently the primary consumer of outfitting parts for the shipyard. In the facility layout(Figure 3) you can locate the various areas that make-up SOC 5 and SOC 6. These areas include:

- Building Ways 3 & 4
- On-Block
- Building Dock 1
- Berths I through XII


BELT ST.
HARBOR DRIVE
GATE 14
GATE 12
GATE 10
GATE 7
GATE 8
GATE 20
SUBLEASE
MASSCO
MAIN
LOT
EXECUTIVE LOT
STIFFENER FAB. AREA
PANEL LINE
PLATE STORAGE
SHAPE STORAGE
BERTH XII
BERTH XI
BERTH X
PIER 12
BERTH IX
FLOATING DRYDOCK
BERTH VIII
BERTH VII
BUILDING WAYS 4
BUILDING WAYS 3
ON-BLOCK
TURN PIT
BUILDING DOCK 1
BERTH I
PROPERTY LINE
T-155
T-117
29
80
57
10

4.1 On-block work center documentation

In the On-Block (SOC 5) area there are approximately 83 designated spaces/work stations as shown in Figure 4. The workstations in SOC-5 are the areas in which steel blocks from steel assembly are brought for outfitting. The workstations have been set up as process lanes as identified by the color designations. These process lanes outfit the various "type" blocks for the SLNC program. The process lanes are identified as follows:

- Non-process lane & deck w/hatch blocks
- Inner bottom blocks
- Non-process lane blocks
- Cargo deck blocks
- House blocks
- Side shell blocks
- Non-process lane machinery units and blocks

The spaces in each of these process lanes are consecutively numbered for identification. The majority of the workstations are of a similar size and configuration. The exact size and configuration of each are identified in figure 5.

Within SOC 5 the steel blocks are outfitted, painted, insulated and prepared for erection and integration into the ship. To support these activities there are multiple material handling devices, work platforms and equipment including: load handlers, fork lifts, high reach equipment and scissor lifts. For large material handling operations in SOC 5 there are several options available. SOC 5 is supported by a fixed position tower crane along with track mounted rolling cranes. The tower crane straddles work stations H17 and H18 and its location is shown in figure 5. The tower crane currently supports the outfitting activities of the various machinery units and engine room blocks which are employed on the SLNC program. The rolling cranes travel the SOC 5 area via the tracks shown in figures 4 and 5. The specifications for both the rolling cranes and the tower crane are shown in figures 6 and 7 respectively.

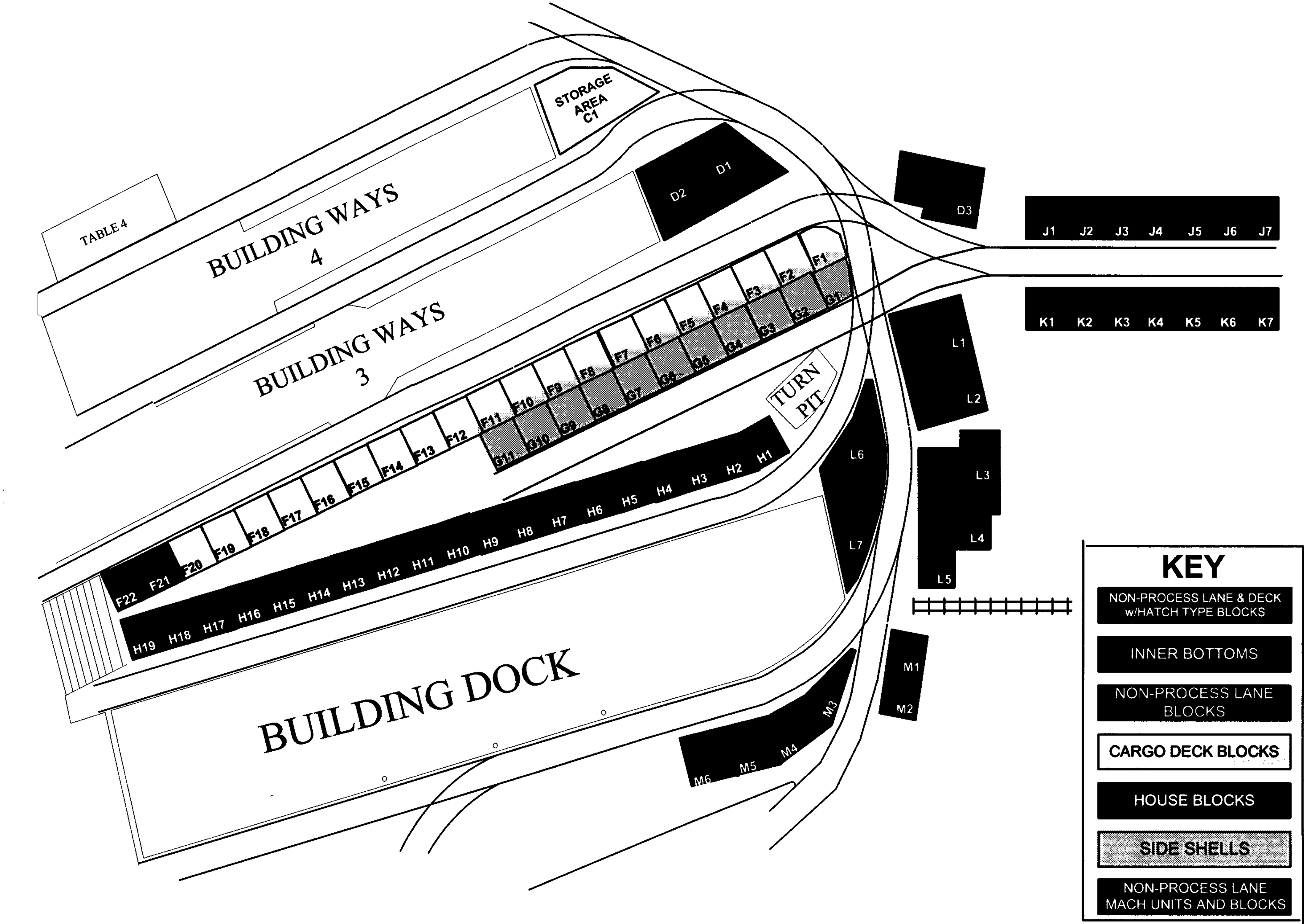


TABLE 4
BUILDING WAYS 4
STORAGE AREA C1
BUILDING WAYS 3
D1
D2
D3
J1 J2 J3 J4 J5 J6 J7
K1 K2 K3 K4 K5 K6 K7
F1 F2 F3 F4 F5 F6 F7 F8 F9 F10 F11 F12 F13 F14 F15 F16 F17 F18 F19 F20 F21 F22
G1 G2 G3 G4 G5 G6 G7 G8 G9 G10 G11
TURN PIT
H1 H2 H3 H4 H5 H6 H7 H8 H9 H10 H11 H12 H13 H14 H15 H16 H17 H18 H19
L1 L2 L3 L4 L5 L6 L7
M1 M2 M3 M4 M5 M6
BUILDING DOCK
KEY
NON-PROCESS LANE & DECK w/HATCH TYPE BLOCKS
INNER BOTTOMS
NON-PROCESS LANE BLOCKS
CARGO DECK BLOCKS
HOUSE BLOCKS
SIDE SHELLS
NON-PROCESS LANE MACH UNITS AND BLOCKS

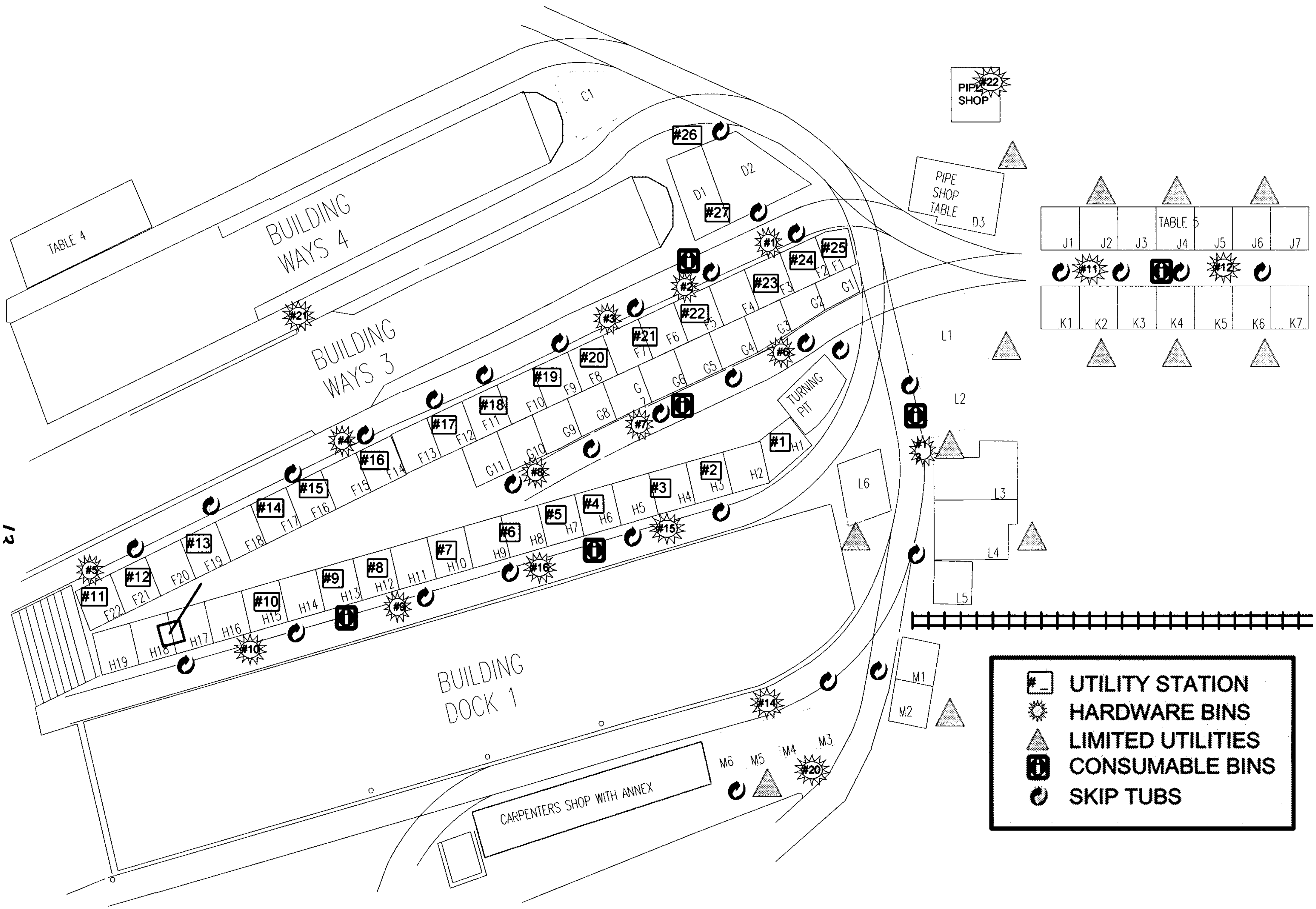


Figure 5
On block work station services

LIFT RADIUS	C CRANE	A CRANE		
METERS	# 2 & 5	# 10 & 11	# 12	# 14
10.6	60			
12.1	55			
13.7	50	95	160	175
15.2	42.5	95	147	140
16.7	37.5	92.5	135	128
18.2	32.5	89.5	125	120.5
19.8	29.5	81	115	113
21.3	26.5	74	108	105.5
22.8	24.5	68	100	98.5
24.3	22.5	62.5	94	92
25.9	20.5	57	87	86.5
27.4	19	52	83	81
28.9	17	48	79	76.5
30.4	15	44	74	72
32.0	14	41	70	68
33.5		38	66.5	64
35.0		35.5	63	60.5
36.5		33.5	59.5	57.5
38.1		31	56	55
39.6		29	53	52.5
41.1		27	50	48
42.6		25	47.5	48
44.1		23		
45.7		21.5		
47.2				
48.7				

In the table shown above a two crane lift is equivalent to 95% of twice the lighter capacity crane. Lift radius is measured from the center of the crane tracks. All capacities are in short tons.

Figure 6

Rolling Crane Specifics

LIFT RADIUS (meters)	WEIGHT (short tons)
38.10	3.1
30.48	4.0
22.86	5.5
0-15.24	8.8

Figure 7

Tower Crane Specifics

To support the outfitting processes that occur in SOC 5 there are services set up in strategic locations throughout the area. The services in the SOC 5 area are shown on Figure 8 and include: utility stations(air, water, electrical grids, industrial gases, etc.), hardware bins(nuts, bolts, washers), consumable bins(gaskets, hanger rubber, insulators, etc.), and skip tubs. In addition to these services there are also several tool rooms located throughout the facility to supply specialized hand and power tools.

4.2 On-board work center documentation

The On-Board (SOC 6) work center actually encompasses several areas and phases of the ship construction cycle. These areas, which were identified earlier on Figure 3, include Building Ways 3 & 4, Building Dock 1 and Berths I through XII. The phases include the erection, zone completion and test processes. These phases are included in the periods of the contract commonly known as keel to launch and launch to delivery.

During the period from keel to launch there are 3 ship erection areas which include Ways 3 & 4 and Building Dock 1. These areas are where Blocks, Grand Blocks, Machinery Units and other interim products are erected to the ship. Each erection area has its own unique restrictions and constraints. Examples of some of restrictions and constraints for Ways 3 are shown in figures 9 and 10. Information about all of the specific facility attributes are contained in facility manuals that are used when developing ship specific build strategies. Figure 9 defines the physical constraints of the ways itself while figure 10 identifies the constraints of the cranes that service ways 3.

As in the case of the SLNC program the erection phase occurs on Ways 3 & 4. The various interim products that are erected for this program are controlled by these facility attributes. Other interim products that would be used in building programs such as container ships or product tankers are controlled by the limiting constraints of Building Dock 1 and the cranes that service it.

During the period between launch and delivery the ship under construction is located in one of twelve berthing locations at NASSCO. For the SLNC program these have been Berths 5 and 6. At these berthing locations the ship is afloat and moored while

it undergoes final outfitting. These final outfitting activities include:

- Final shafting, reduction gear & gas turbine alignments
- Diesel generator alignment and light off
- Completion of system testing in prep for trials
- Load out of materials and spare parts for owner

Like the other facilities at NASSCO, each berthing area has its own unique attributes and constraints. The table identified as Figure 11 identifies each of the berths along with their physical sizes and capacities. It also defines the services that are located at each of the berths and capacities of the cranes that are capable of servicing each of these locations.

During the on-board phases of the ship construction cycle there are multiple tools that are used for managing the production activities. Most of the tools that have been found to be most effective are those that are of a visual nature. An example of one of these tools is shown in Figure 12. This figure is a weekly progress chart that is used to monitor progress by zone. The colors are used to monitor progress on a weekly basis by zone and are coded as follows:

actual more than 5% behind plan

actual +/- 5% to plan

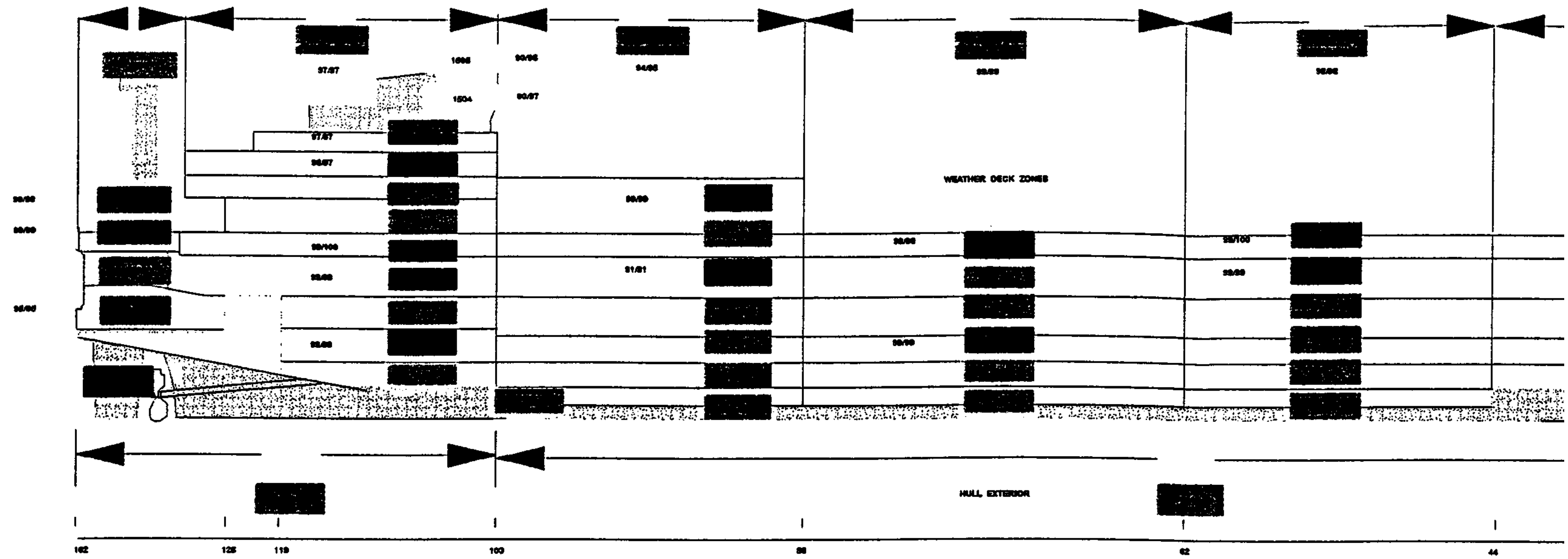
actual more than 5% ahead of plan

progressed at 100%

progress at 0%

In addition to this weekly progress chart there are also star charts for managing the erection schedules, activity Gantt schedules and PERT charts.

SEALIFT X PLANNED/ACTUAL PROGRESS AS OF WEEK XX
HULL 45X



VERTICAL ZONES:

1402 GTRB COOL AIR SUPPLY TRUNK
1403 INTAKE/EXHAUST
1104 CHAIN LOCKER

PAINT SUPERZONES:

16/16 1000
33/37 1090
1100
1300
1301
1302
1303
1304

TANK ZONES:

1201 FOREPEAK TANK
1211 NO. 1 SWB TANK
1212 COFFERDAM/DEEP TK DFM S/P
1221 NO. 2A WING TK SWB S/P,FIXED BALLAST
1222 NO. 2B WING TK SWB S/P
1223 COFFERDAM/NO. 2C WING TK SWB S/P
1231 NO. 3 DB FWD TK S/P, 3A WING TK S/P
1232 NO. 3B WING TK DFM S/P
1233 NO. 3 DB AFT TK S/P, 3C WING TK S/P
1234 NO. 3D WING TK DFM S/P
1241 OILY WASTE TK, NO. 4 WING TK
1242 LIST CONTROL TK SWB S/P, COFFERDAM
1251 L/O STORAGE, DIESEL FUEL, ETC.
1261 MACHY RM SRVCES/BALLAST TANK
1262 AFT PEAK BALLAST TANK

FUNCTIONAL ZONES:

1001 OUTER HULL SHAFTING & P
1002 INNER HULL SHAFTING
1003 GAS TURBINE
1012 TWIN CRANE & BOOM REST,
1013 TWIN CRANE & BOOM REST,
1014 STORES CRANE
1015 BOAT DAVITS
1016 ELEVATOR
1021 SIDEPORT DOOR, STBD
1022 SIDEPORT DOOR, PORT
1023 STERN RAMP

5. Current outfit material flow

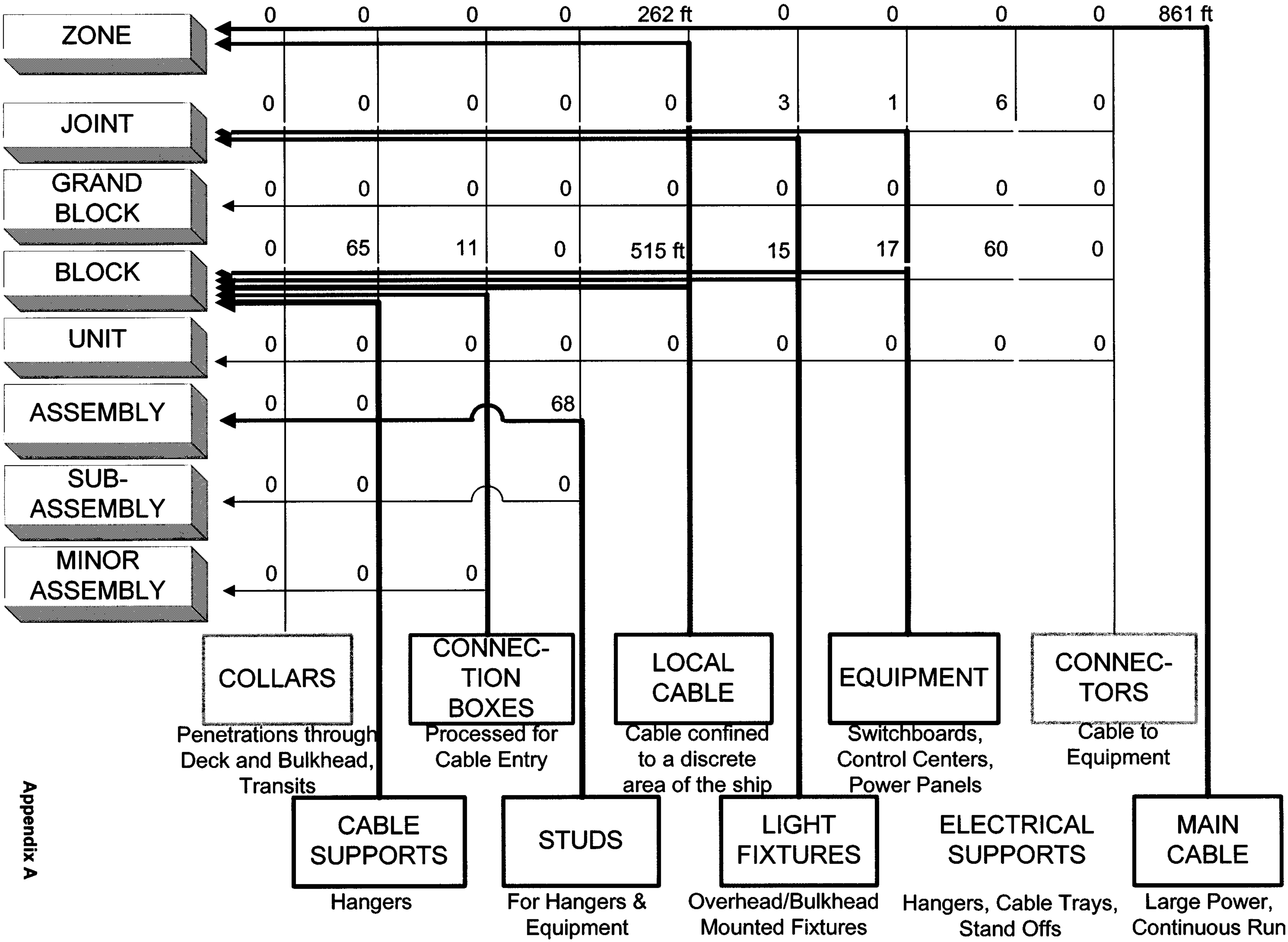
As was stated previously, during development of SLNC strategies concerted efforts were made to move towards an interim product approach. This was done effectively in some areas, but the majority of the ship was still designed using a traditional outfitting approach. This traditional outfitting approach, or block and zone outfitting, creates the need for a large number of outfitting parts to be brought to the workstations that consume them. In the case of the SLNC these are the On-Block and On-Board areas.

The majority of current outfit interim products that are employed at NASSCO are primarily lower level products such as parts, spools and minor assemblies. These components are either fabricated in shops on site, or are "bought in" components from vendors and suppliers. In order to install the numerous outfitting parts into the On-Block and On-Board areas each part must be delivered to the area along with the steel blocks that the parts are installed onto.

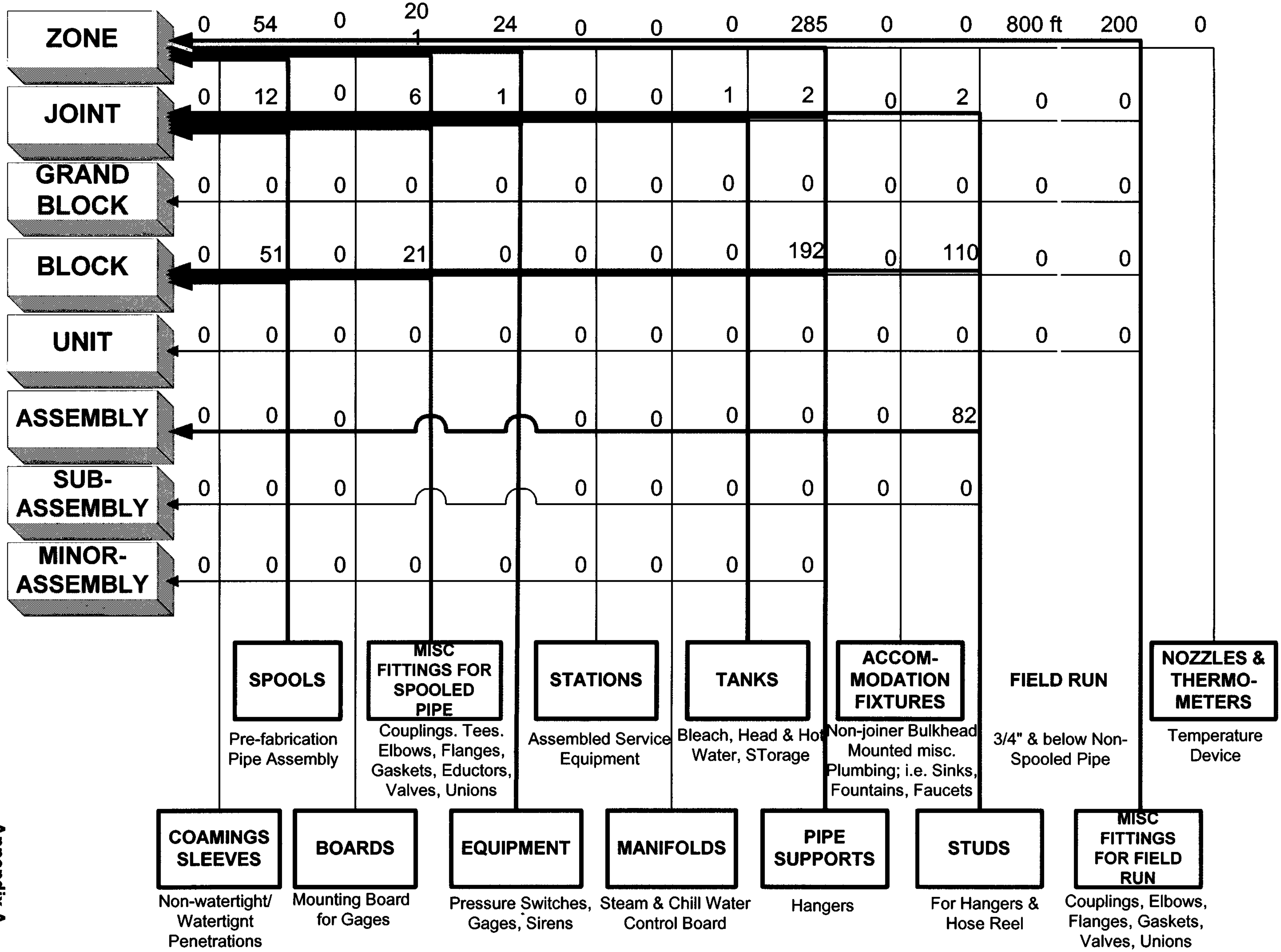
As was identified earlier, Figure 3 identifies the On-Block and On-Board areas. The steel blocks are brought to the various process lanes in the On-Block area via rolling cranes. In just about every case these blocks must be transported through a specific area of the yard where the crane tracks intersect which is located immediately in front of the pipe shop, building 29 of Figure 3. Additionally, the numerous outfitting parts that are brought from the pipe shop, electric shop, metal outfitting shop, sheetmetal shop and warehousing must also be transported through this same area via cranes, fork lifts, load handlers and material trains on its way to the On-Block and On-Board work stations. In some cases these materials or components must cross this area multiple times, such as equipment going to the machine shop for mounting or machining or outfitting going to the steel area for installation.

It should also be noted that there is additional congestion through this area with the daily personnel traffic along with the raw material deliveries to each of the fabrication shops.

ELECTRICAL PRODUCT STRUCTURE FOR NASSCO TRADITIONAL OUTFITTING METHOD

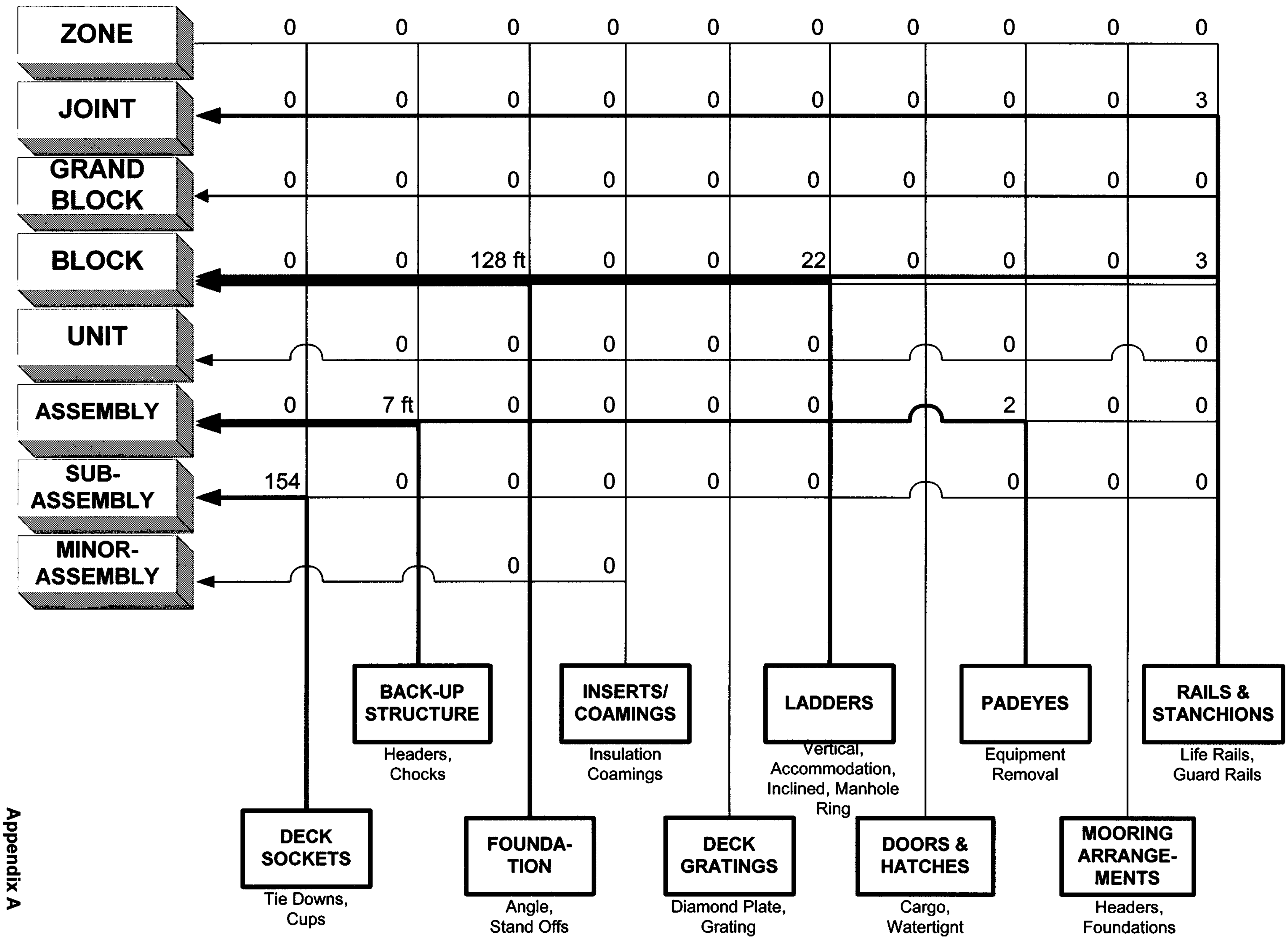


PIPING PRODUCT STRUCTURE FOR NASSCO TRADITIONAL OUTFITTING METHOD

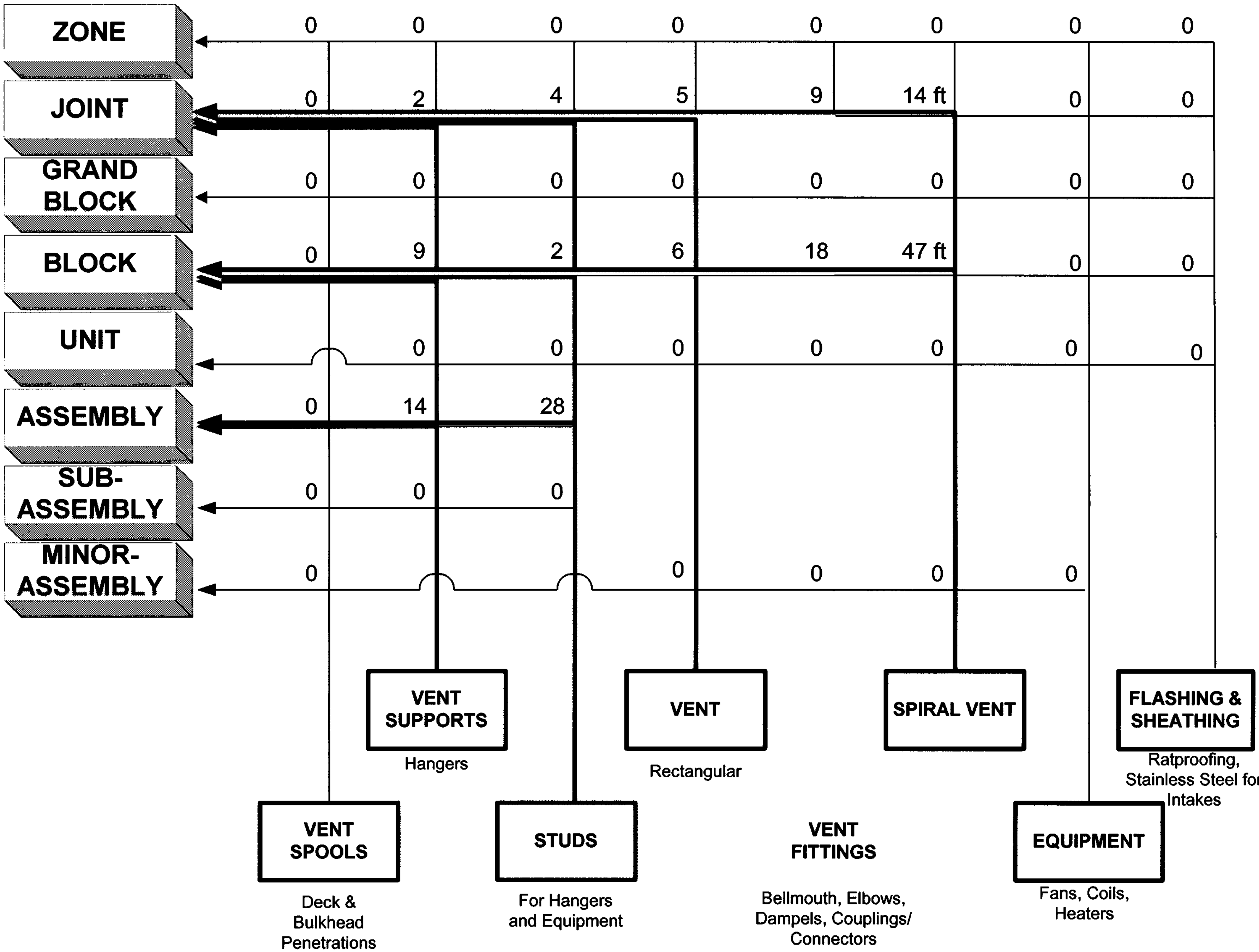


Appendix A

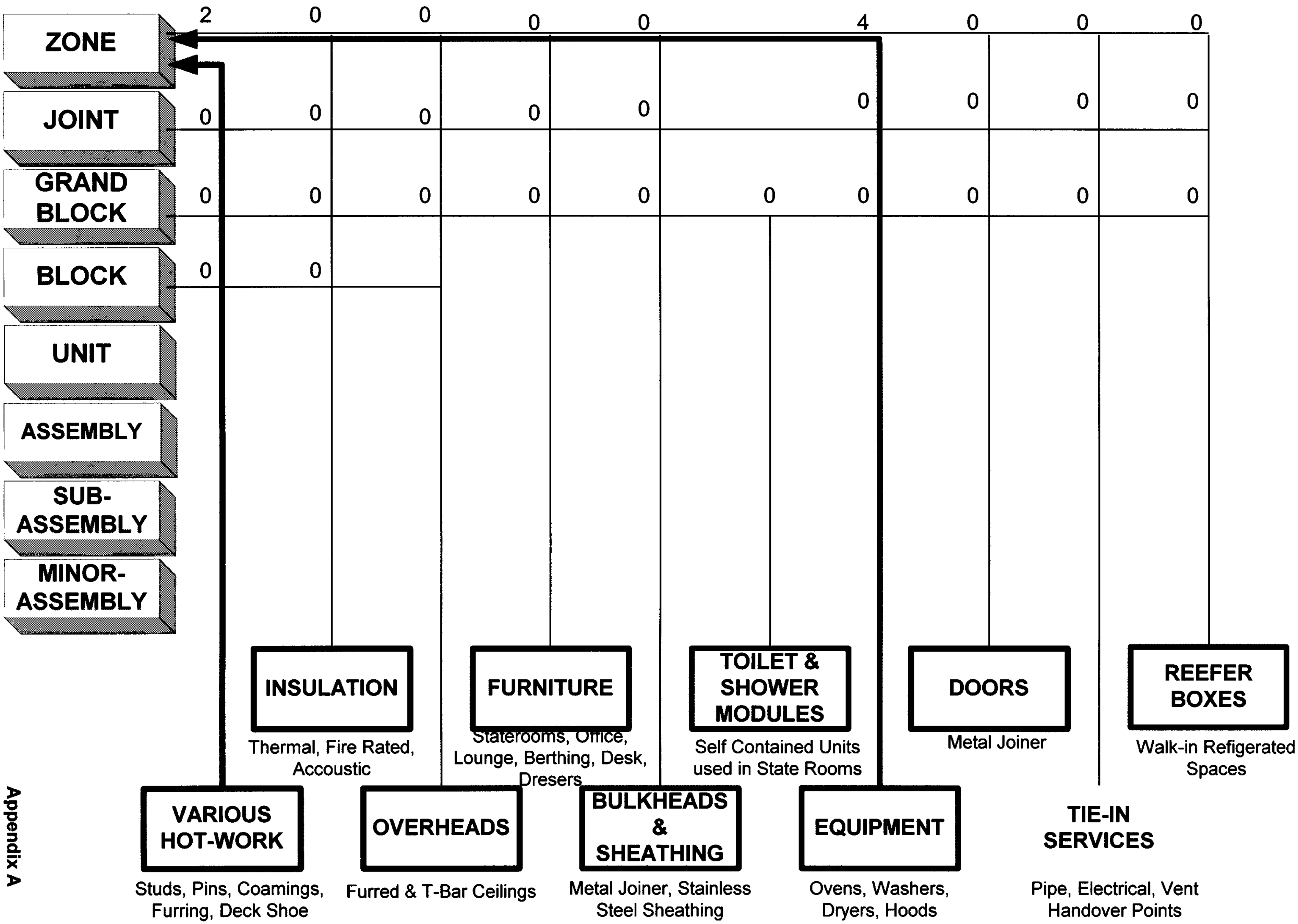
METAL OUTFITTING PRODUCT STRUCTURE FOR NASSCO TRADITIONAL OUTFITTING METHOD



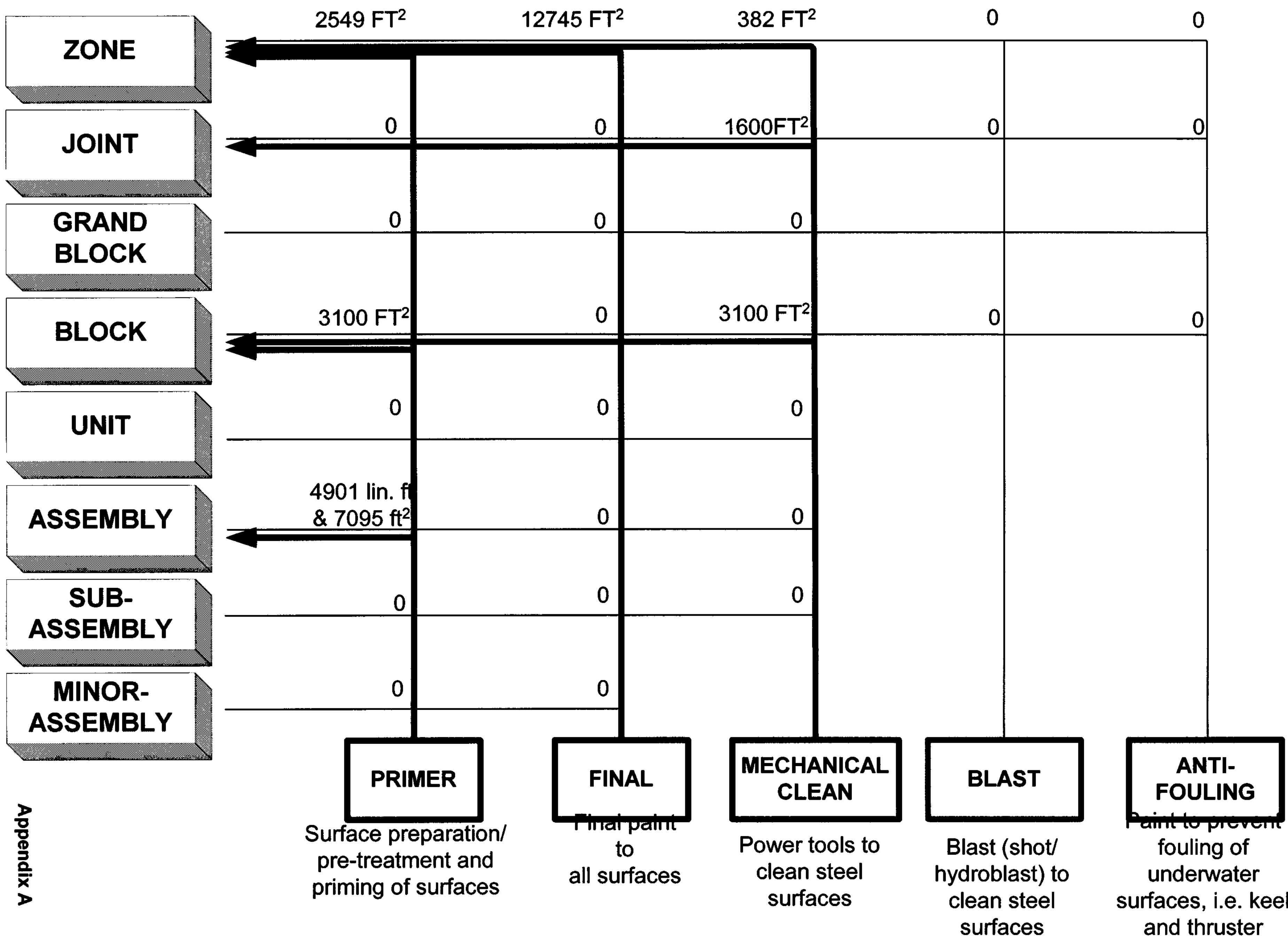
VENTILATION PRODUCT STRUCTURE FOR NASSCO TRADITIONAL OUTFITTING METHOD



JOINER PRODUCT STRUCTURE FOR NASSCO TRADITIONAL OUTFITTING METHOD

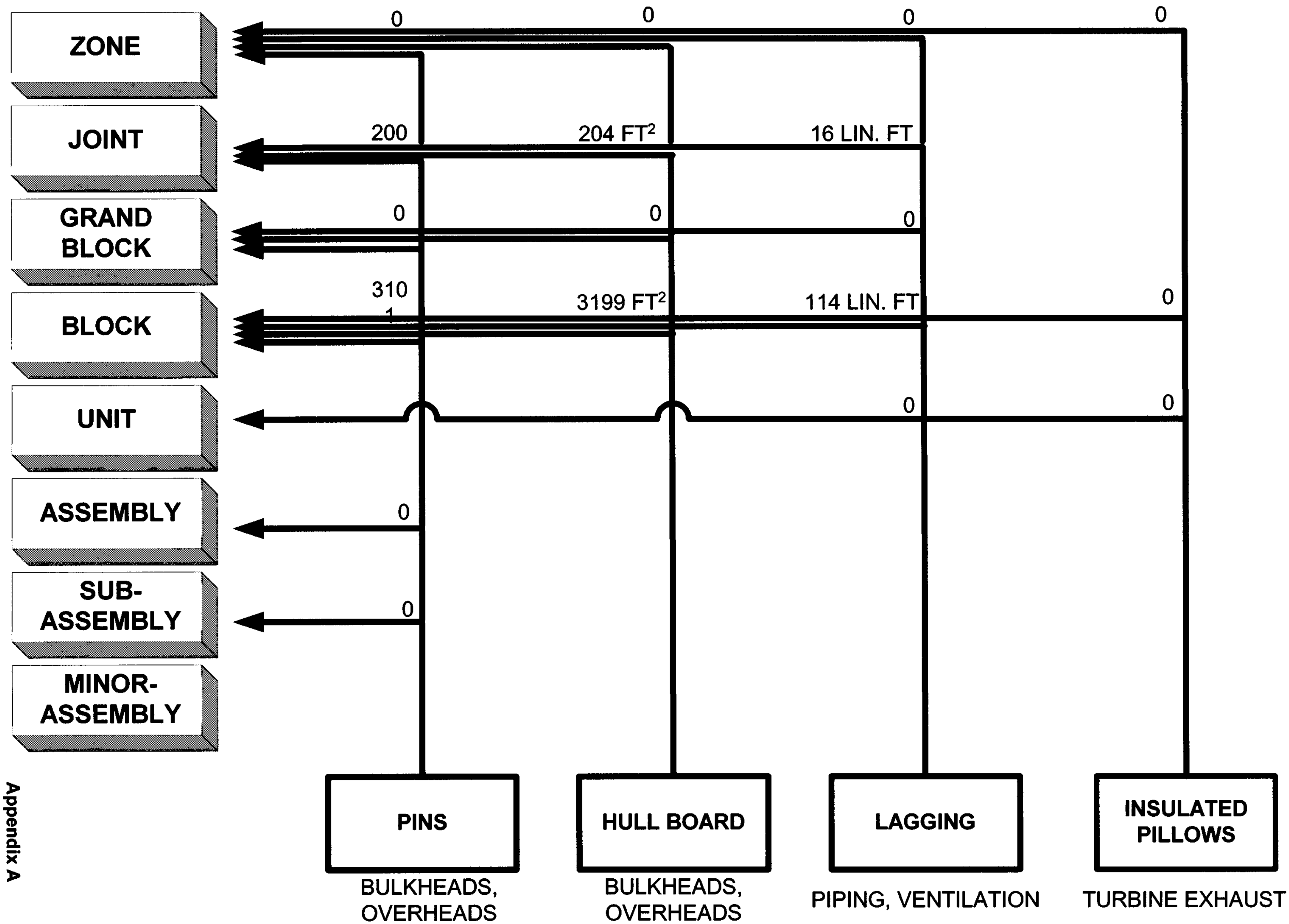


PAINT PRODUCT STRUCTURE FOR NASSCO TRADITIONAL OUTFITTING METHOD



Appendix A

INSULATION PRODUCT STRUCTURE FOR NASSCO TRADITIONAL OUTFITTING METHOD



NATIONAL STEEL AND SHIPBUILDING COMPANY

NSRP PROJECT 8-98-2

Process Modeling to Improve Productivity of On-Board and On-Block Outfitting

Task 3 Deliverable

World-Class Outfit Production Process Activities

FIRST MARINE INTERNATIONAL LIMITED

February 1999

Document World-Class Production Process Activities

CONTENTS

1 INTRODUCTION

This document forms part of the NSRP Project 8-98-2, Process Modeling to Improve Productivity of On-Board and On-Block Outfitting. The primary objective of the project is to establish a world-class methodology for the definition of outfit interim products, which can be competitively assembled and installed on a vessel in a multi-trade work environment.

The objective of this document is to describe a world class product-oriented, workstation philosophy for outfit production activities. Also, a means for developing a structured set of design and engineering rules and decision making criteria, which when applied during the pre-production process, provides a consistent and logical method for the definition of outfit interim products. The approach involves defining a hierarchical interim product structure for the assembly and installation of outfit elements. From this, process lane and workstation operation models are generated to illustrate the methodology. Although not strictly within the terms of reference, the document refers to the development of a product oriented design and engineering process as a major factor in the development and implementation of the interim product structure.

2 DESIGN PROCESS FOR OUTFITTING

The successful implementation of a product oriented workstation philosophy requires that the design and engineering process is similarly product oriented. That is to say, that for outfit, a hierarchy of multi-system assemblies or interim products are pre-defined and applied during the design and engineering process. These outfit interim products are integrated with the main structure at the optimum time in the assembly and construction cycle. Interim products must be clearly defined with all associated production attributes and consistently applied throughout an integrated design and engineering process to define the construction of a vessel.

To develop a product oriented approach; a generic interim product structure is generated as a first step. This is based upon the constraints of the facility and optimization of the production processes and is used to reflect the impact of an interim product structure throughout the design and engineering process. The interim product structure forms part of the company shipbuilding strategy, which defines how the shipyard conducts its business. From the shipbuilding strategy, the generic interim product structure is applied during the design of new vessels. The use of pre-defined interim products significantly reduces the pre-production lead-time and man-hours traditionally associated with the development of a new ship design. Also, having a defined shipbuilding strategy enables the implications of a change in product, method or process to be fully analyzed prior to implementation on a live contract and reduces the extent of production unknowns, inherent in a traditional system oriented approach. In a product oriented workstation environment the shipbuilding strategy approach is possibly the most important element in the stabilization of the ship design and construction process and is essential in sustaining continuous performance improvement.

The initial development of a company shipbuilding strategy should ideally be carried out independent of a specific vessel design and should consider all vessels in the company product range. However, if a shipyard does not have a defined product range it is possible to develop the shipbuilding strategy concurrently with a new vessel design. If this is being attempted it is important to clearly distinguish between what is generic and therefore applicable to all vessel types and what is ship specific. Only generic information is encapsulated in the shipbuilding strategy. Adopting a concurrent approach enables the majority of interim products to be defined during the design and engineering cycle of a single vessel.

2.1 Developing design for production guidelines

The successful implementation of a product-oriented philosophy relies heavily upon the design and engineering department's full understanding of the interim product structure. In an ideal world it

would be possible to fully develop a new vessel design entirely from the range of interim products as defined in the shipbuilding strategy which maximizes the utilization and performance of the existing facilities. However, this is rarely the case and the design and engineering departments have to be capable of customizing the generic interim products to suit the functional requirements of a specific vessel. Therefore, it is essential that all members of the design and engineering departments are fully familiar with the interim product structure and its application. Thus, allowing the creation of a specific ship design from an aggregation of optimally designed interim products.

To ensure a consistent application of the interim product structure, a series of design rules and decision making criteria are attached as attributes to each of the interim products defined in the shipbuilding strategy. These provide a set of 'design for production' work instructions, which are developed for each interim product, at each stage of the design process. In this manner the production engineering intent is incorporated at the earliest concept design stage and subsequently developed with increasing levels of detail throughout the design and engineering process.

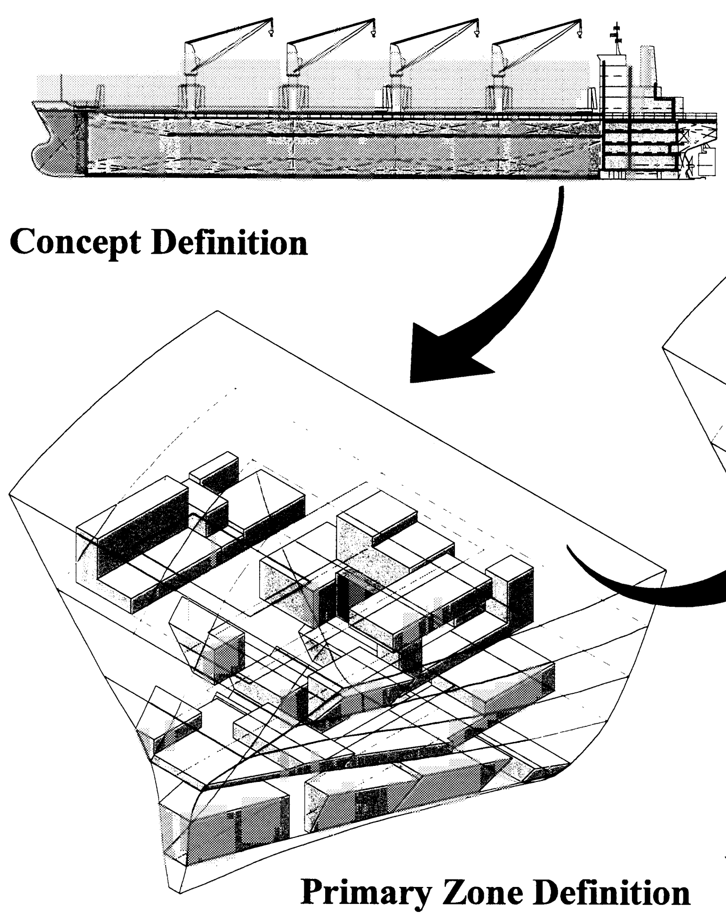
It is important to note that the interim product design rules and decision-making criteria are the key to a successful product oriented ship definition process. It is equally important to appreciate that the development of these rules and criteria is not a one-time effort. Whenever new products, methods, processes or facilities are being introduced the interim product structure and design rules must reflect the change.

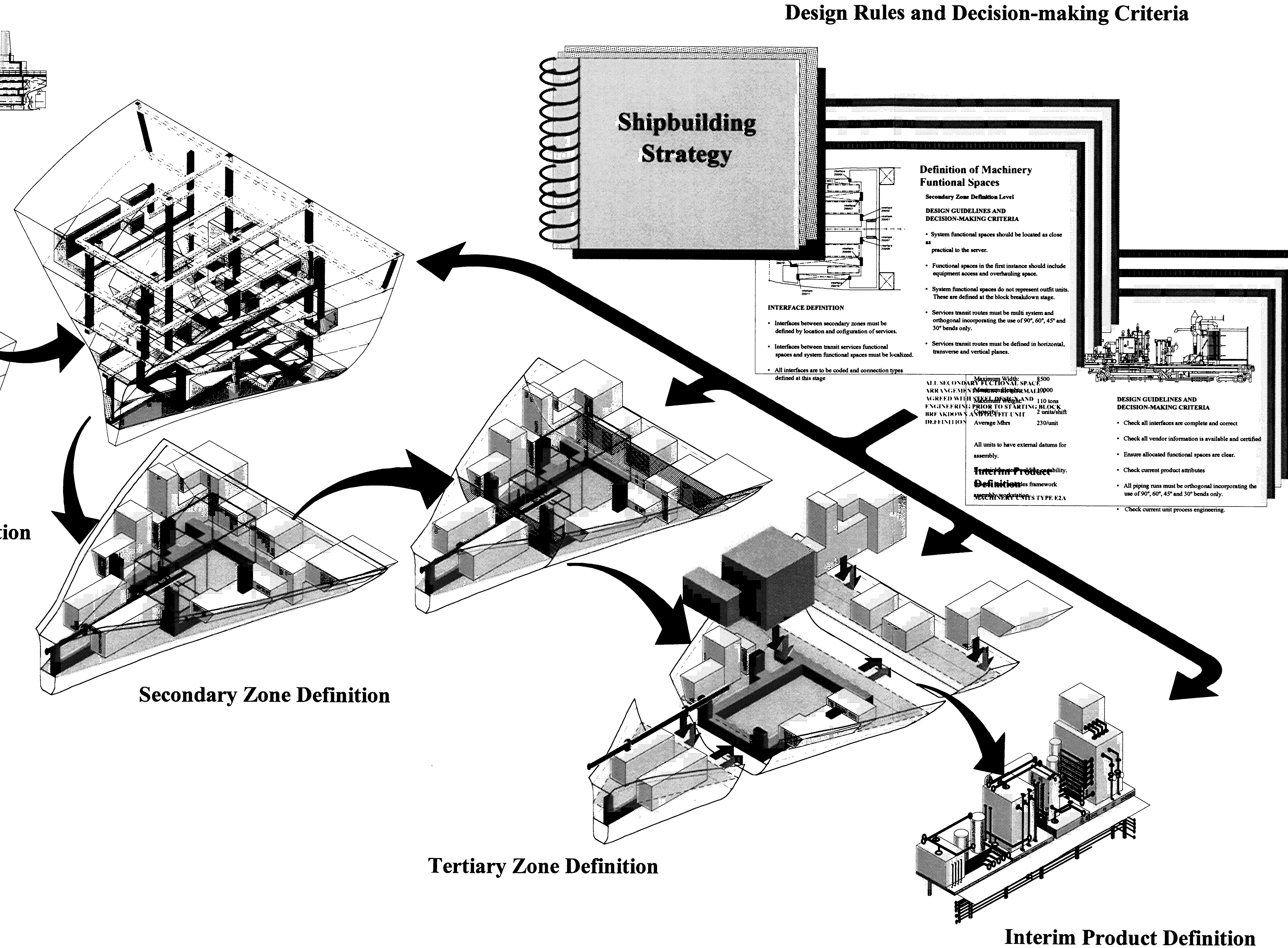
2.2 The ship definition process

The ship definition process develops the design and production definition of a vessel through a series of steps that progressively detail the functional spaces of the vessel from primary zone spatial layouts to the detailed engineering of the final product, as shown in Figure 2.1. Throughout this design process the shipbuilding strategy provides the designers and engineers with a series of work instructions. This ensures that the design of a specific vessel optimizes the utilization of facilities, processes and manpower as well as meeting the functional requirements of the owner and regulatory bodies.

The work instructions incorporate product oriented principles and are presented in the form of clear engineering instructions applicable for each stage of design. For example, at the concept stage they provide overall instruction for developing systems and functional space allocation to take account of the major interim product types. Later, detailed instructions are provided for the design of each interim product type and for the preparation of workstation information. This allows the designers and engineers to translate general 'design for producibility' principals into specific shipyard 'design for

production' rules associated with the interim product types which are most economically produced in the production workstations.





Process for the Production Definition of a Vessel

The process flow for the production definition of a design follows the sequence of developing an overall concept and by progressively increasing the level of function space definition develops the final interim products for production.

At each stage of the definition process the capabilities of the shipyard are introduced through the Shipbuilding Strategy which defines the interim products that can efficiently be made by the shipyard, and its sub-contractors, within the constraints of the current facilities.

The Shipbuilding Strategy provides the designers and engineers with a series of design rules and decision-making criteria for each interim product type. This producibility of a vessel to be balanced with the functional requirements of the specification.

Figure 2.1

Production Definition Process

3 INTERIM PRODUCT STRUCTURE FOR OUTFITTING

As described previously, the methodology is to develop a product oriented approach defining operations and production attributes to a hierarchy of interim products that maximize performance of the current facilities and to encapsulate this in a company shipbuilding strategy. Any new product or process design development is carried out prior to incorporation in the shipbuilding strategy. In this way the effect of any new product or process can be simulated and the effect on all the interrelated functions fully analyzed prior to inclusion in the shipbuilding strategy and subsequent implementation through the design and engineering process.

The first task is to define the interim products. For steelwork it is comparatively easy to define the range of interim products and to group them by similar process into product families ranging from piece parts to major block types. Outfit is somewhat different and has traditionally been seen as a series of relatively small individual system items generally fitted on the steelwork at the on-block and on-board stages. Thus, there has been little need to define an interim product hierarchy and product families. This philosophy has changed with the recognition that outfit performance can be significantly improved through the application of the same assembly principles used for steelwork and the integration of steel and outfit throughout the production process.

It is important to note that the definition and subsequent updating of the design rules and decision making criteria for each interim product type, at each stage of the design process, is crucial in implementing a product oriented philosophy. It must also be understood that the shipbuilding strategy, which incorporates the design rules, is dynamic and consequently the design rules and decision-making criteria will continuously evolve as facilities, methods and processes are developed.

3.1 Types of outfit interim products

When developing a range of outfit interim products there are some which can be regarded as being independent of the structural constraints and based more on the functional areas where they are located. Typical examples of independent outfit interim products include:

- cabin modules for accommodation areas,
- services transit modules which group pipes, vents and electrical services into common racks,
- equipment modules which combine aspects of the above into an engineering based assembly of framework, equipment and services.

When outfit products are integrated with structural interim product types they form integrated interim products which are usually based on the structural products. Typical examples include:

- minor and sub assemblies such as floors and girders with manholes, penetrations, inserts and handholds,
- major structural panels which may include all the above together with foundations, backing structure and some services, and
- blocks that may include the full range of outfit interim products.

The final installation of outfit parts at erection joints and in shipboard zones should be regarded as a different set of interim products based upon stages of completion rather than assembly hierarchy. Typical examples of joint and zone interim products include:

- structural and outfit join-up parts at ship erection, and
- parts for the onboard completion of compartments or open deck areas.

In the case of outfit parts, interim product families are generally defined by system, such as pipework, ventilation, foundations, ceilings, bulkheads and linings, furniture, doors and windows, electrical cable and equipment, insulation, painting, deck coverings and soft furnishing. A simple system for illustrating how these outfit interim products are grouped is shown in Tables 1 and 2.

As can be seen, the type of interim product is referenced by a simple code such as D-1-a for an equipment assembly. A code similar to this should be developed for linking product types to preferred workstations for manufacture. Applied during the design and engineering process, a meaningful code will enable the workloads for each workstation to be readily assessed from the quantities of each product type used in a new design.

PRODUCTION STAGE		PRODUCT TYPE		PRODUCT FAMILY	
A	Outfit Parts	1	Metal Outfit	a.	foundations/back-up structure
				b.	inserts/coamings/sockets etc.
				c.	deck gratings
				e.	ladders
				f.	doors & hatches
				g.	pad eyes
				h.	rails & stanchions
				i.	electrical/pipe/vent supports
		2	Piping	a.	pipe spool families
				b.	small bore field run
				c.	manifolds
		3	Sheet Metal	a.	spiral & rectangular ducting
				b.	ventilation penetrations
				c.	flashing and sheathing
				d.	ventilation equipment
		4	Joinery	a.	ceilings, bulkheads & linings
				b.	furniture
				c.	doors & windows
		5	Equipment	a.	main propulsion
				b.	auxiliary equipment
				c.	deck machinery
				d.	mooring fittings
				e.	steering gear systems
				f.	cargo loading systems
				g.	personnel elevator
				h.	toilet and shower modules
		6	Insulation	a.	insulation pins
				b.	lagging/insulated pillows
		7	Painting	a.	primer/ final/ anti-fouling
				b.	mechanical clean/ sand blast
		8	Deck Coverings	a.	screed
				b.	carpet/linoleum
		9	Electrical	a.	main/local cabling
				b.	main electrical equipment
				c.	connectors/connection boxes
				e.	light fixtures
		10	Soft Furnishing	a.	bedding, curtains etc.

Figure 2.1 – Typical Outfit Part Families

PRODUCTION STAGE		PRODUCT TYPE		PRODUCT FAMILY	
B	Minor Assembly	1	Outfit Minor Assemblies	a.	small assemblies of pipe or vent.
				b.	small assemblies of equipment.
				c.	small control panel assemblies.
		2	Steel Minor Assemblies	a.	flat plate stiffeners.
				b.	webs and transverses.
C	Sub - Assembly	1	Service Assembly	a.	racked assemblies of vents, pipes etc.
				b.	walkway and ladder assemblies.
		2	Module Assembly	a.	steel structure, equipment, vents, pipes and other services.
		3	Steel Sub-Assemblies	a.	flat panel assemblies with outfit.
				b.	curved panel assemblies with outfit.
				c.	complex sub-assemblies with outfit.
				d.	flat matrix assemblies with outfit.
				e.	complex 3d assemblies with outfit.
D	Unit Assembly	1	Equipment Assembly	a.	steel framework structure with vents, pipes, cabling & equipment items.
		2	Cabin Assembly	a.	cabin and integrated services.
				b.	toilet and shower modules.
E	Block Assembly	1	Integrated Steel Block	a.	curved panel blocks with outfit.
				b.	double skin blocks with outfit.
				c.	flat built-up panel blocks with outfit.
				d.	deck and shell blocks with outfit.
				e.	superstructure blocks with outfit.
		2	Equipment Block	a.	steel framework structure with vents, pipes, cabling & equipment items.
F	Joint Assembly	1	Grand Block Interface	a.	Structural block interface.
				b.	Outfit block interface
		2	Ship-Block Interface	a.	Structural block interface.
				b.	Outfit block interface
G	Grand Block	1	Integrated Steel Block	a.	curved panel blocks with outfit.
				b.	double skin blocks with outfit.
				c.	flat built-up panel blocks with outfit.
				d.	deck and shell blocks with outfit.
				e.	superstructure blocks with outfit.
		2	Equipment Block	a.	steel framework structure with vents, pipes, cabling & equipment items.
H	Zone Assembly	1	Zone Completion	a.	fully bounded areas.
				b.	partially bounded deck areas.
				c.	external hull areas.
I	Test & Commission	1	Ship Systems	a.	all systems completed, tested and commissioned.

Figure 2.2 – Typical Outfit Assembly Families

3.2 Consistent assembling of outfit interim products

One of the most important elements for the effective implementation of a hierarchical interim product structure is maintaining consistency in the sequence and processes for assembly. Traditionally, outfitting is carried out during the later stages of construction such as the pre-outfitting of completed steel blocks and on-board installation. Recent developments in ship production technology are leading to the development of a fully integrated steel and outfit construction process. This means that steel and outfit interim products are combined at the optimum stage in the build process. Figure 3.1 demonstrates that it is possible to combine parts and assemblies of all types at various construction stages this provides flexibility of design and planning.

The level of outfit integration at each construction stage is dictated by whether it is the best time to install the outfitting elements and whether the finished product can be efficiently produced within the constraints of the facilities. However, regardless of the extent of outfit integration during the assembly process there will always remain an amount of outfitting to complete onboard. Depending on the location of erection joints, outfitting at the erection stage can minimized. Similarly, the level of on-board zone completion is significantly effected by the size of the erected blocks and a block breakdown that has been developed without consideration of outfitting.

3.2.1 Consistent product hierarchies

In addition to maintaining production consistency, it is equally important to maintain consistency in the definition of interim products. As all interim products, structure and outfit, are treated in the same manner it is possible to develop a generic description for the construction of all types of interim product. This is essentially a 'type plan' showing the sequence and types of interim products within a block type or zone usually depicted in the form of a product hierarchy diagram or family tree, as shown in Figure 3.1.

This family tree enables designers and engineers to efficiently 'build' their block interim product structure schematically while developing the functional arrangements within the primary zones of the ship. Initially, the types and numbers of structural and outfit blocks can be defined quite early in the design process with little detailed information. Each block or zone family tree is then refined as the ship specific details are developed. This effectively builds the roots of the family tree using lower level interim product information from the shipbuilding strategy.

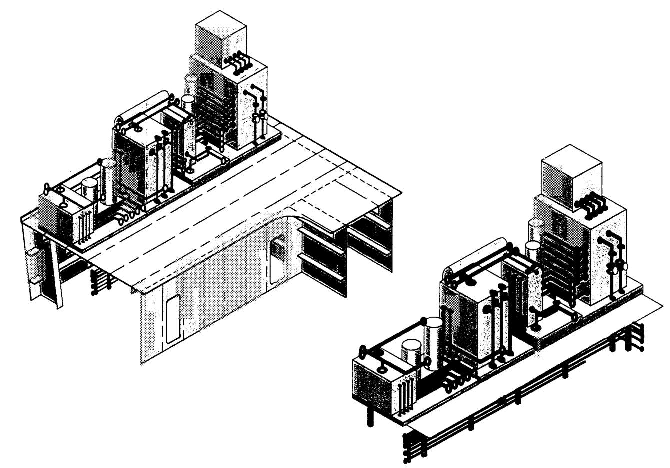
The use of the shipbuilding strategy and 'type plans' enables a designer to quickly identify assemblies that can be made repeatable, either within a primary zone or throughout a ship. This approach is a major benefit to the pre-production functions as it gives them the ability to significantly reduce man-hours and lead time for the development of production information.

Assembly of Interim Products

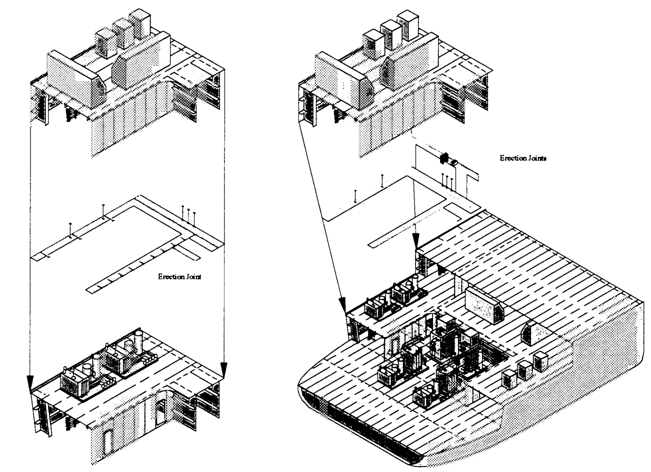
Within the major product types of Block, Joint and Zone. There is a hierarchy of lesser interim products that can be combined in various quantities and combinations to produce any of the larger products.

This is shown by the simplified product hierarchy which shows how each level of products from parts to assemblies can combine with each other to produce the required larger interim product. In this manner what appears to be a unique product is in fact a unique aggregation of standard interim products.

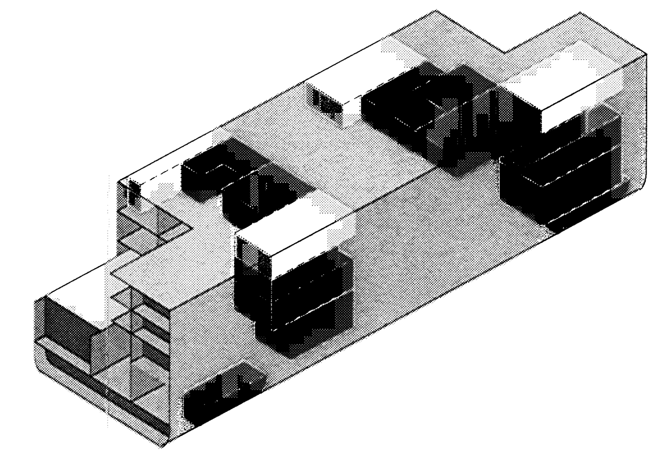
Structural and Outfit Block Assembly



Grand Block Assembly and Ship Erection



Onboard Zone Completion



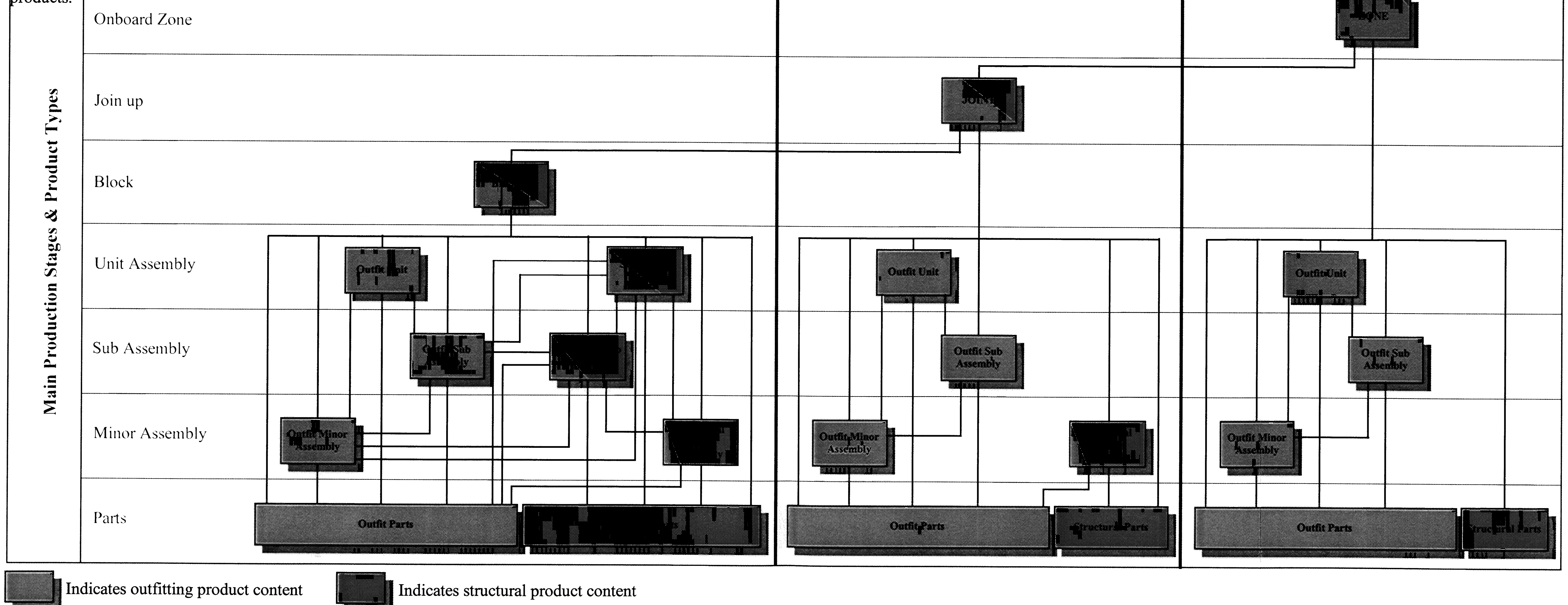


Figure 3.1

Consistent Hierarchical Product Structure

3.3 Developing outfit interim product families

The definition of an outfit interim product structure that maximizes the capabilities of the shipyard is a key factor in achieving high performance. As stated previously, the development of the outfit interim product structure and definition of product families forms part the company shipbuilding strategy which ensures that all products defined for a vessel match the capabilities of the production facilities. In some cases, this can be expanded to include the production capabilities of subcontractors.

The methodology used to develop an outfit interim product structure is similar to that applied for steelwork. First the principle stages of production are defined together with the basic product types and initial product families as shown in figures 2.1 and 2.2. Secondly, each product family is associated with a production area. A detailed process analysis of the production areas, process lanes and workstations provides a set of design criteria for the product families which reflect the facility constraints and process capabilities which interim products within that family must comply with to maximize the work area performance. Following the production process analysis, the basic product types and initial product families are refined and finalized to match the actual capabilities, constraints and operations of the facilities.

When developing the range of interim product families it is important to ensure that shipyard personnel understand the basis for the selection and grouping of particular product types. This base information includes:

- the type of product and generic name,
- a simple graphical representation of each of the product attributes which maximize production process performance, and
- physical limitations imposed by facility constraints such as length, width, height and weight.

When compiled for each interim product family a set of illustrations or 'product family album' is compiled similar to that shown in Figure 3.2. This album of product families is crucial in the first stages of implementing an interim product structure. It ensures a common understanding of the structure and the production areas and process lanes dedicated to the manufacture of the product families.

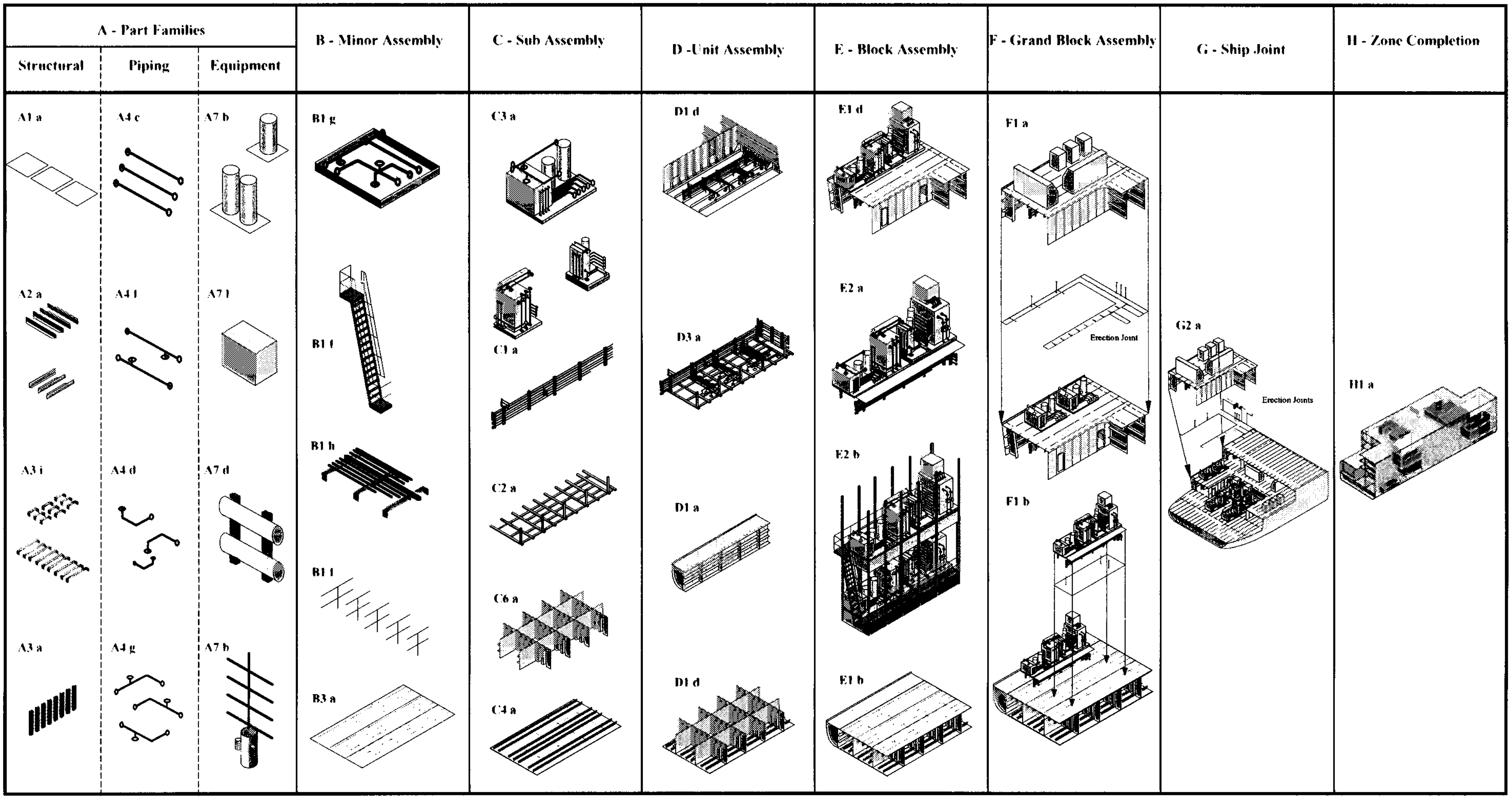


Figure 1 - Interim Product Family Album

Interim Products at the Block Stage

The majority of interim products are absorbed up to the block assembly stage. It is crucial that the process engineering is well thought out and maximizes the use of the generic interim product structure.

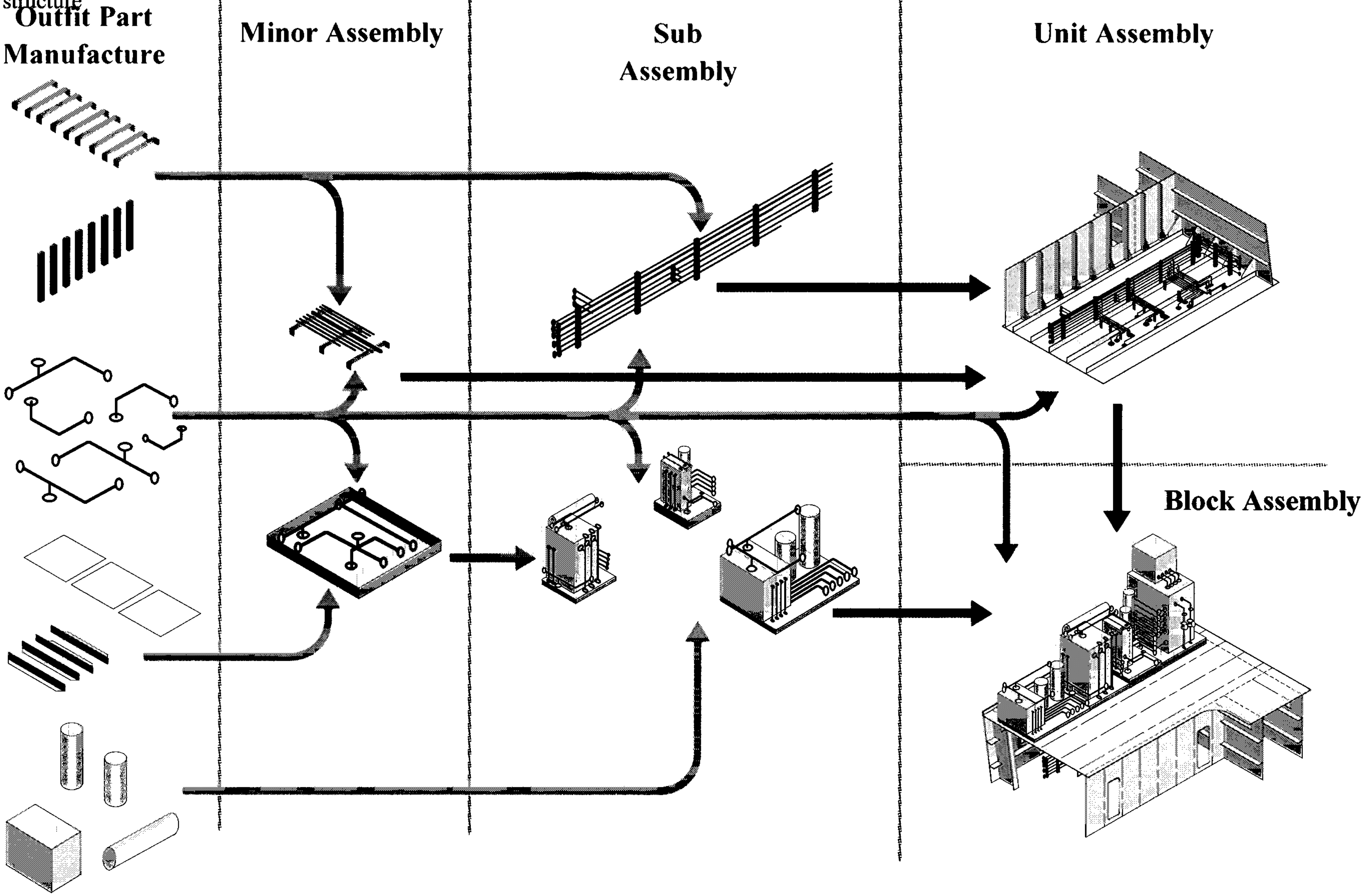
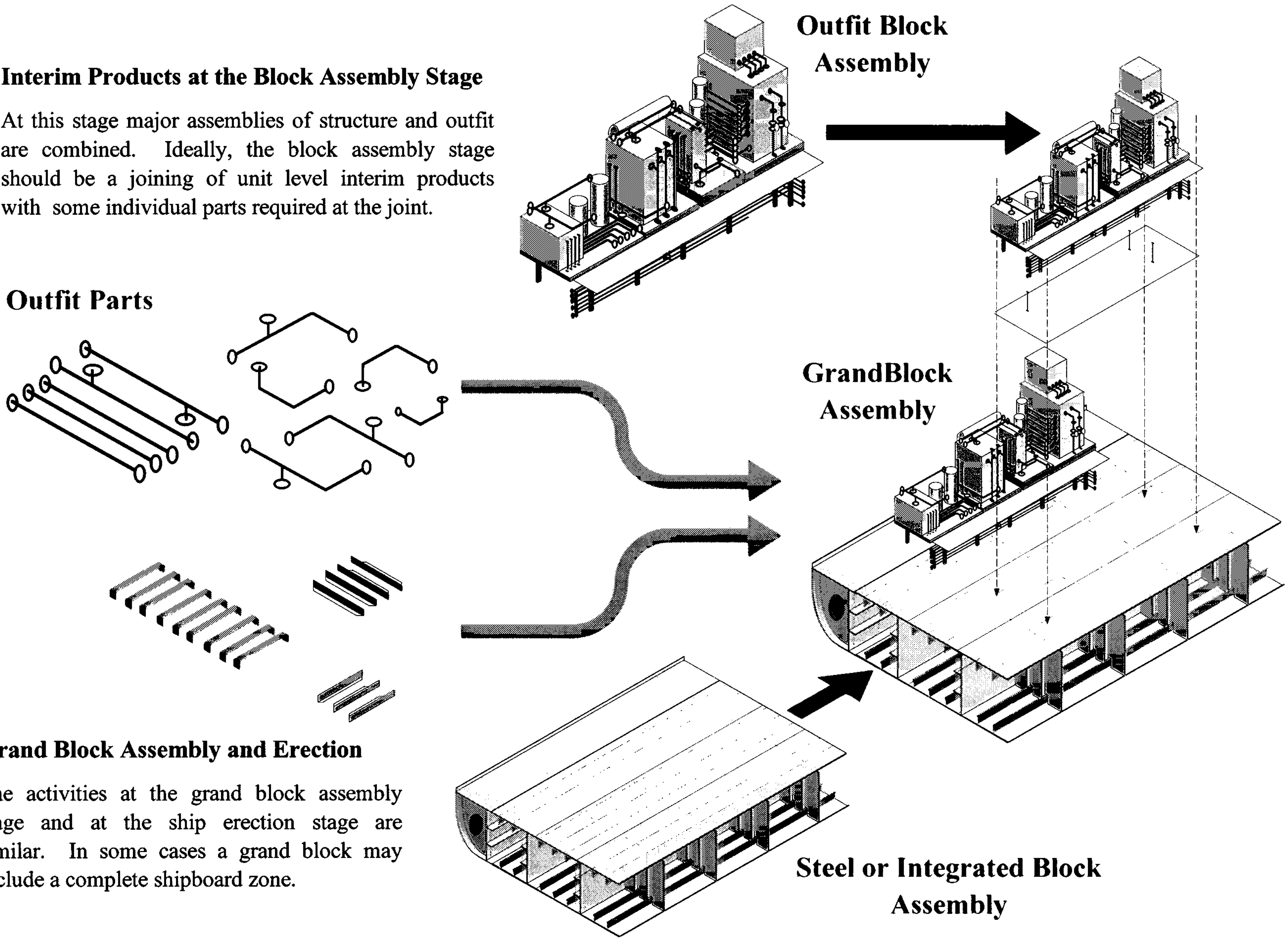


Figure 3.3

Simlified Block Outfit Process Engineering

Interim Products at the Block Assembly Stage

At this stage major assemblies of structure and outfit are combined. Ideally, the block assembly stage should be a joining of unit level interim products with some individual parts required at the joint.

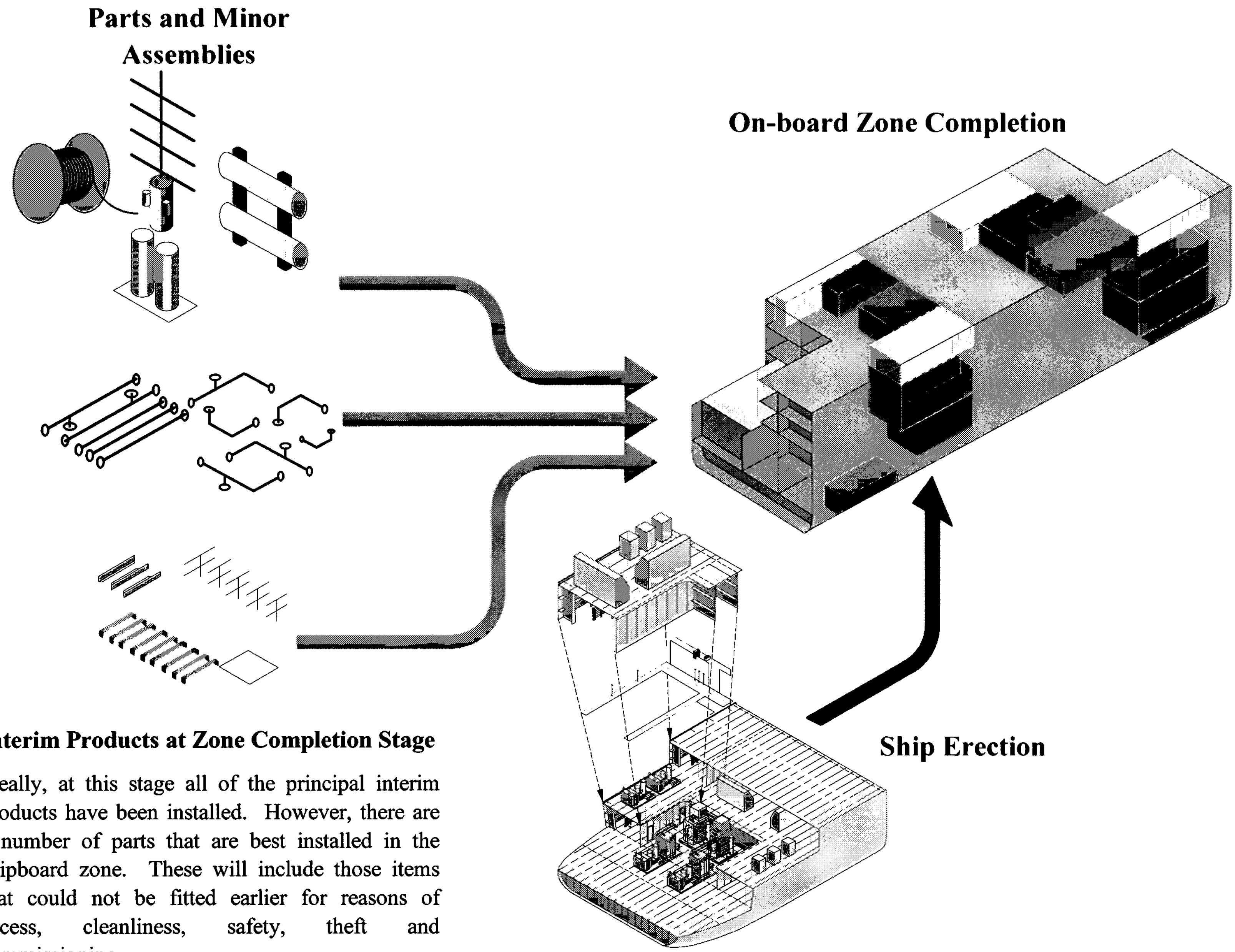


Grand Block Assembly and Erection

The activities at the grand block assembly stage and at the ship erection stage are similar. In some cases a grand block may include a complete shipboard zone.

Figure 3.4

Interim Products and the Join-Up Stage



Interim Products at Zone Completion Stage

Ideally, at this stage all of the principal interim products have been installed. However, there are a number of parts that are best installed in the shipboard zone. These will include those items that could not be fitted earlier for reasons of access, cleanliness, safety, theft and commissioning.

Figure 3.5

Zone Completion Interim Products

4 THE OUTFIT ASSEMBLY PROCESS

Traditionally, outfitting is considered as a separate stage in the construction of a vessel. The majority of the work being carried out after the vessel is afloat. In this traditional approach, stages of outfitting are generally defined by trade and outfit system. This is illustrated in the upper portion of Figure 4.1.

By comparison, modern shipbuilding technology considers steel and outfitting as integral parts in the assembly process. Many world class shipyards are moving towards an integrated construction approach. This has developed the understanding that effective integrated production requires integrated design and engineering and a reorganization of the design and engineering functions on a primary zone basis rather than the traditional steel and outfit system organization.

The approach to outfitting assembly process engineering is similar to that for steel. Multi-system assemblies are defined in a hierarchy of interim products, which are integrated with the steelwork at the optimum time in the assembly and construction sequence. However, unlike steelwork, outfitting involves a wider variety of materials and mix of trade skills. Therefore, the type of outfitting carried out in the various stages of assembly must be considered very carefully and be clearly defined. For example, if fragile elements of outfit are integrated too early in the assembly sequence they are prone to damaged and subsequent replacement. The lower portion of Figure 4.1 shows a methodology for defining multi-system stages for outfitting integrated with the steel assembly process.

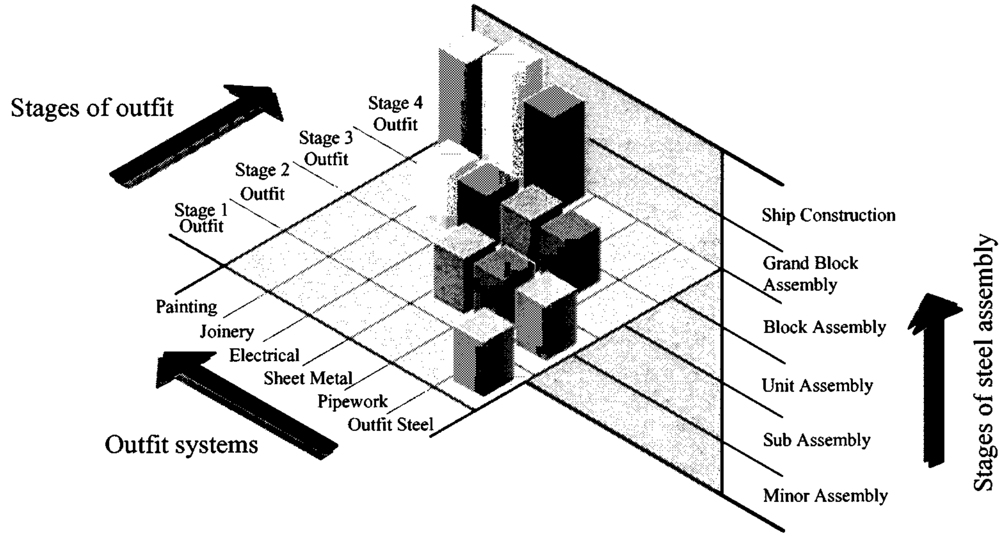
First each outfitting system is analyzed and the sequence of installation defined. Following that, the steel assembly sequence is defined and the optimum time to install a stage of outfitting is determined. It is important that all outfit systems are considered simultaneously so that rework, which may result from having to remove some items in order to install others at a later stage, is avoided. Also, subsequent stages of assembly must be considered to avoid damage during fitting and handling activities.

When this exercise has been completed it becomes possible to develop a matrix similar to that shown in the lower right of Figure 4.1. This shows the volume of outfitting by system carried out at each stage in the assembly process. Each horizontal level in the matrix indicates the mix of outfit trade skills required at the integrated assembly workstations. This is illustrated in the lower left of Figure 4.1.

Clearly, adopting a multi-system by stage approach in production has considerable impact in the preparation of production information. Traditionally, production information and production planning workpackages are prepared by system and occasionally by stage, although this is usually confined to

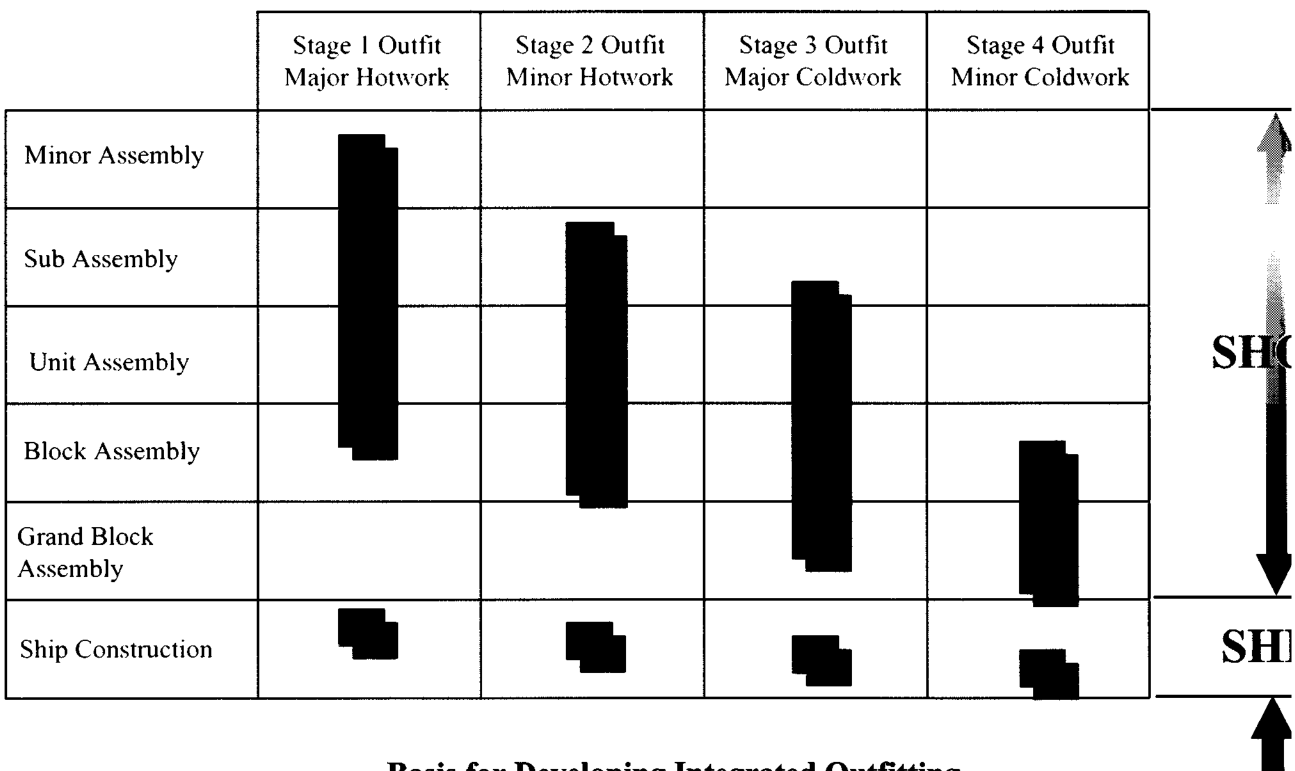
on-unit and on-block outfitting. A multi-system by stage approach necessitates a totally different approach to the development of production information.

In a commercial shipbuilding environment, design lead times and production cycle times tend to vary depending upon contractual requirements and it is not always possible to achieve the optimum steel/outfit integration. Developing a multi-system by stage approach provides the means of determining the effect of moving outfit activities between assembly stages. When used in conjunction with flexible zone definition and the ability to isolate the status of individual ship systems the multi system approach provides a highly flexible and responsive outfitting methodology.



Traditional System Based Outfitting Methodology

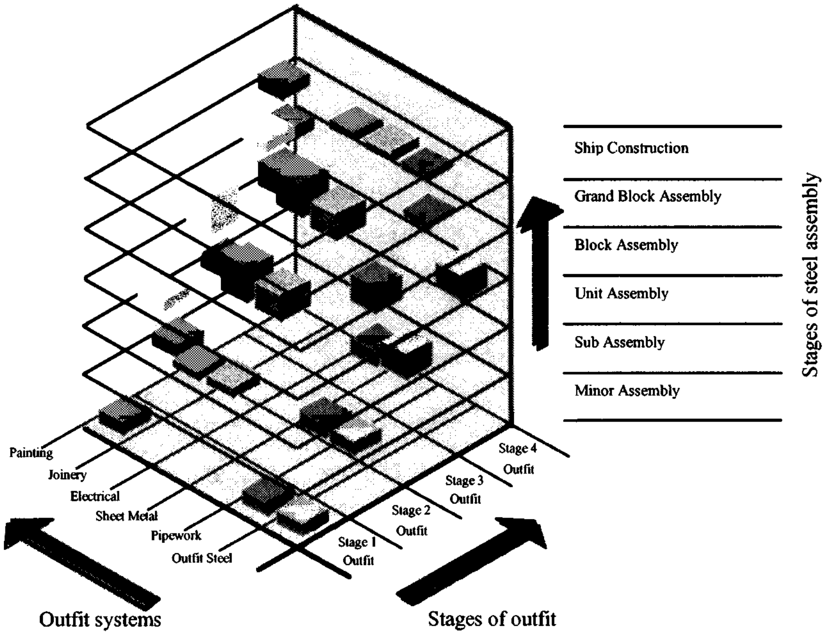
Traditionally, outfit systems such as pipes, vents, electrical etc. were left to the later stages of the build sequence. Stages of outfit installation are system based and the sequence of work was generally by trade.



Basis for Developing Integrated Outfitting

Analysis of outfitting systems and the sequence of installation will define the optimum stage of construction for integration with the steel structure. The trend should always be as shown above. That is, major hotwork at the earlier stages to minor coldwork at the later stages.

Outfit Products and the Structural Assembly Process



The two diagrams to the left and below illustrate the effect of integrated construction. The general methodology is to install outfit at the earliest, most cost effective stage of production. This does not mean that all items are installed as early as possible. There are a number of items which are best installed at the grand block assembly stage or in the on-board zone.

Intalling outfit items in earlier stages of construction is not sufficient to improve the overall cost of assembling a ship. Maximum effect can only be achieved by applying a modular production philosophy through the definition of a hierarchy of interim products. When deciding when is the most appropriate time to incorporate outfit products it is important to examine each product type assembly hierarchy and each outfit system in order to define the best stage of construction for integration.

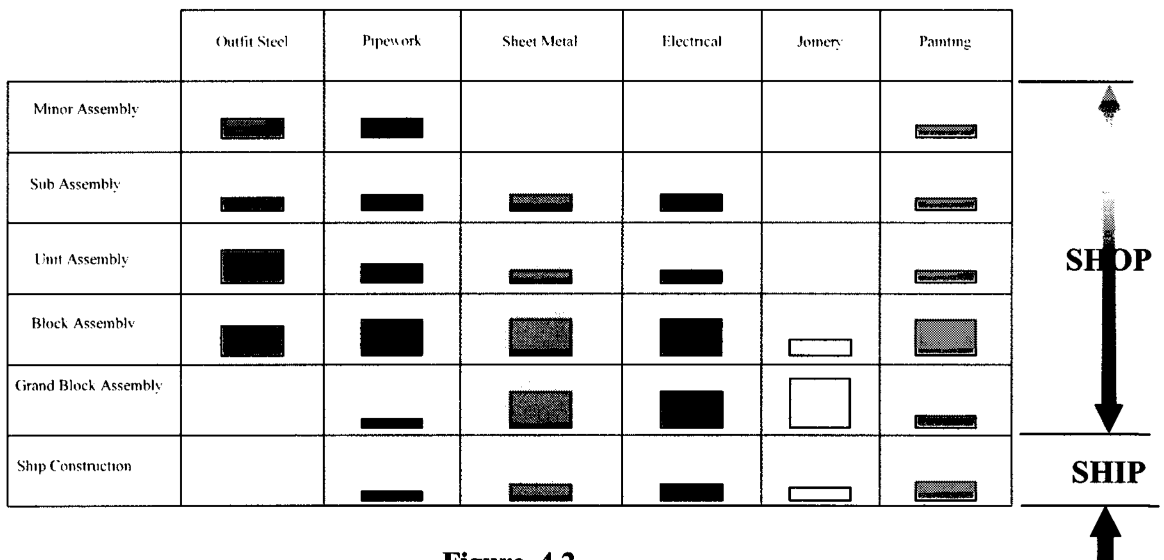


Figure 4.2

Integrating Outfit Products with Structure

4.1 Integrated assembly work centers

Inherent in the design of each interim product family are restrictions imposed by the constraints of the facilities, production processes and skill levels of the workforce. These attributes are a major part of developing the design criteria associated with interim products and enable the association of products to work centers, process lanes and workstations. Attributes range from high level ship/shipyard criteria, required at the earliest concept design stage, to the product/workstation criteria for individual interim products.

Unlike structural steel, an outfit interim product structure involves a wider variety of product families. In most shipyards the lowest level, that of outfit parts, is usually well defined, as they are readily identifiable with specific manufacturing processes and machines. However, a hierarchy of outfit assemblies is generally not so clearly defined and consequently the process engineering exercise is critical for the initial definition of integrated workstations and outfit assembly process lanes necessary to implement the change in shipbuilding methodology.

4.2 Outfit assembly process flow and workstations

Adopting a hierarchical interim product structure for outfitting requires a significant change in technology to that needed for traditional pre-outfitting of blocks. Traditional pre-outfitting involves the installation of outfit parts onto the steel blocks prior to erection. Consequently, the only facility requirement is for additional lay-down area to allow for the pre-outfitting activity. However, an integrated assembly methodology with a defined outfit interim product structure requires highly organized processes lanes and workstations for outfit product assembly.

To obtain maximum benefit from an integrated construction approach it is important to consider the steel assembly facilities and process flow when designing the outfit process lanes. Figure 4.2 illustrates the integration of steel and outfit interim product process lanes. It demonstrates the flexibility of a well-defined outfit interim product structure by showing how the same outfit interim products can be integrated with the steelwork at various stages in production.

The type and number of outfit assembly process lanes required depends on the variety of outfit interim products required to satisfy the shipyard's product range and the throughput requirement. In some cases the volume of a particular product type may not justify the development of a dedicated process lane. In this case the yard must decide whether to re-engineer the interim product, produce it in an 'off-line' assembly area or form partnerships with sub-contractors. In the latter situation a

subcontractors facilities can be considered as part of the shipyard facilities and consequently the constraints and process limitations will dictate the interim product attributes and therefore influence the design criteria.

Process Flow for Integrated Assembly

An integrated product assembly factory treats all products the same. Each product type must be built at an appropriate workstation with the required tooling and operator skills. The layout ensures that material handling and transportation of products is minimized while maintaining the flexibility to supply finished products to the appropriate workstation.

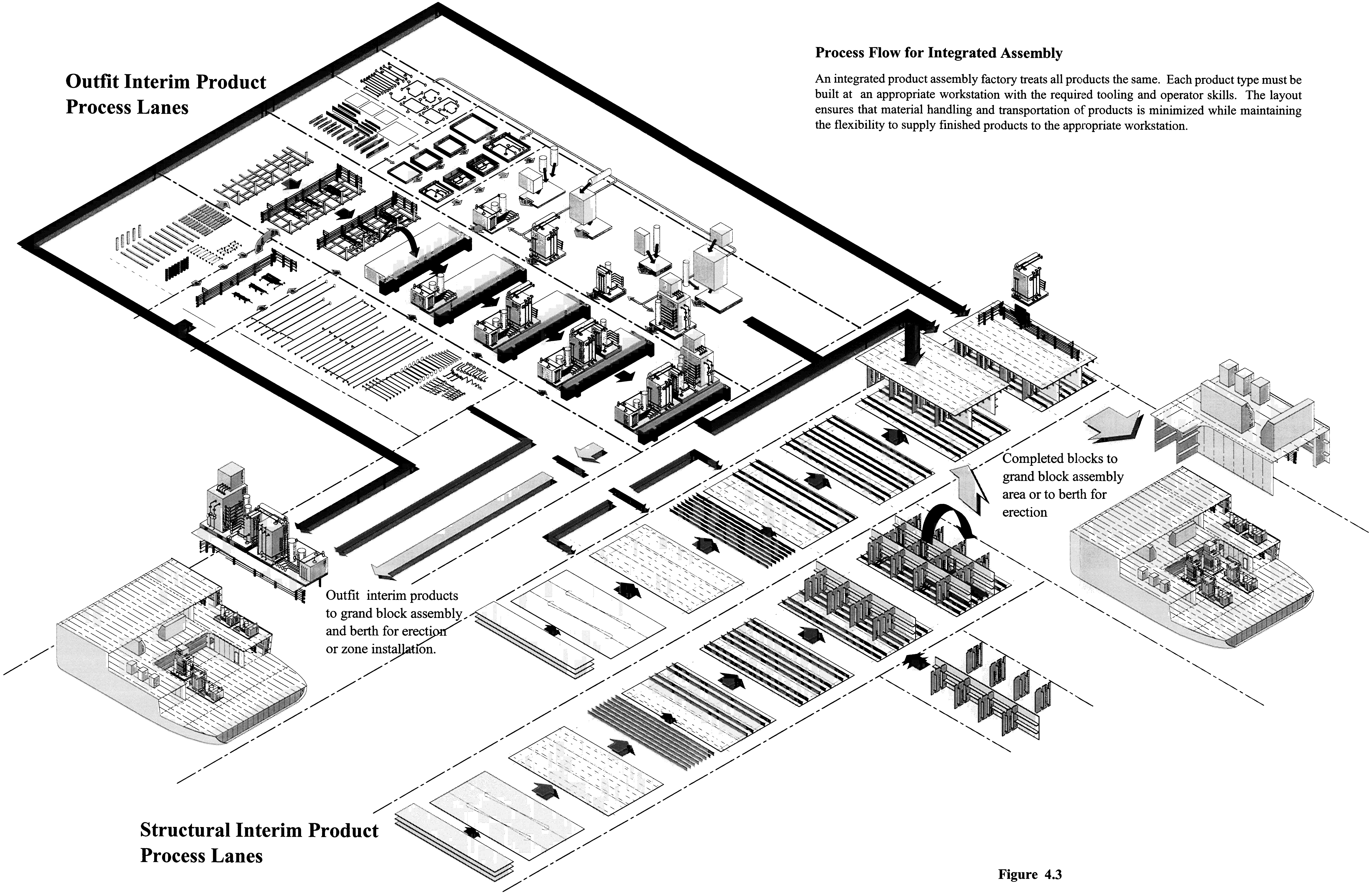


Figure 4.3

The Integrated Structure and Outfit Process Flow

5 OUTFIT INSTALLATION PROCESS

On-board installation is an area often overlooked when implementing a product oriented and workstation approach to design and construction. However, it is essential that this stage be rigidly controlled if costs and timescales are to be reduced. As described earlier, outfitting can be categorized into four general stages. These are:

- Stage 1 Outfit – Heavy Hotwork, consisting of major structural connections, foundations, piping penetrations, ventilation penetrations, electrical penetrations, watertight doors, windows, hatches, mooring fittings etc.,
- Stage 2 Outfit – Minor Hotwork, consisting of studs, hangers, internal bulkhead and ceiling supports etc.,
- Stage 3 Outfit – Heavy Coldwork, consisting of installing equipment, piping, vents, cabling, internal bulkheads, ceilings, furniture etc.
- Stage 4 Outfit – Minor Coldwork, consisting of fitting insulation, painting, lighting etc.

A fifth stage of outfit, generally not considered as part of the construction process, is preparing a vessel for delivery. This includes placing on-board loose items prone easy damage or theft such as soft furnishing, small electrical items, tools, spares, charts, fuel, consumable stores, etc.

The stages of outfit described above are not hard and fast demarcations of work rather they are general guides for the organization of work. In practice there will be an overlap across the stages as the work is integrated throughout the assembly process. However, the stages do become more pronounced during on-board installation and can be used as an effective zone-by-stage planning and control mechanism.

5.1 The rolling wave approach to on-board outfitting

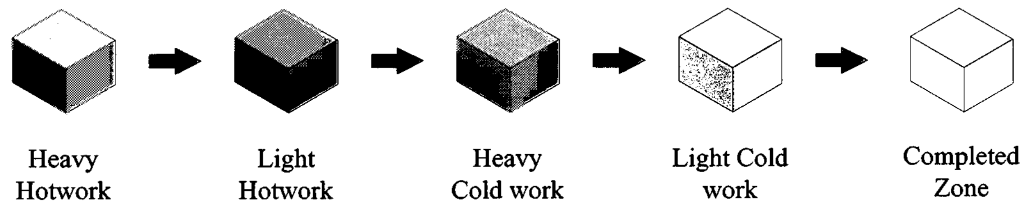
The key to an effective on-board outfitting program is the ability to progress the completion of shipboard zones in a structured manner. Applying the zone-by-stage method described above, outfitting is progressed through the work stages. This is illustrated by the upper diagram in Figure 5.1, which represents the on-board completion of a zone applying the outfitting stages. In practice, multi-skilled teams of production workers rotate through the zones in sequence completing the workpackages defined for each outfitting stage.

The work sequence begins with the erection of the block that closes a shipboard zone. Workpackages are defined so that each production team moves through the zone in equal cycle time, as shown in the

center diagram of Figure 5.1. In practice, this is achieved by allocating teams to primary zones of the ship such as, machinery space, accommodation space and cargo spaces where the type of work is similar. This 'rolling wave' principle can be applied to the on-board outfit of all ship types. The most crucial element for the effective application is a flexible zone definition system that enables secondary and tertiary zones to be varied to better balance work content. The lower diagram in Figure 5.1 shows a simplistic view of the 'rolling wave' principle beginning with block erection through the subsequent stages to zone completion.

Zone Work Stages

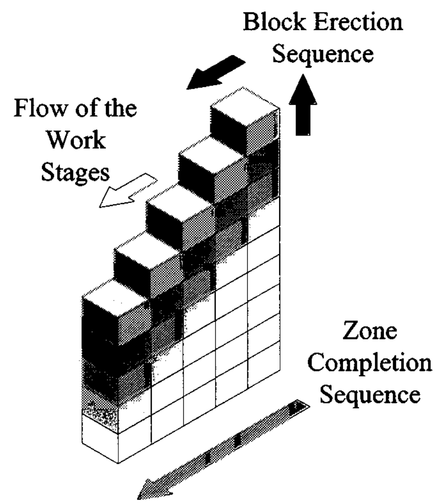
The work stage in each zone is represented by a colored cube. In simplistic terms each color denotes a type of work that must be completed before the next starts. In practice, there is a degree of overlap as some work can run concurrently without interference.



Stages of completion in a Zone

As the zones become available after the close-out block erection. The first stage production team, moves through each zone in a defined sequence. They are followed by the second stage production team then the third and so on. This work flow forms a 'rolling wave' of zone-by-stage progress until the each zone is completed.

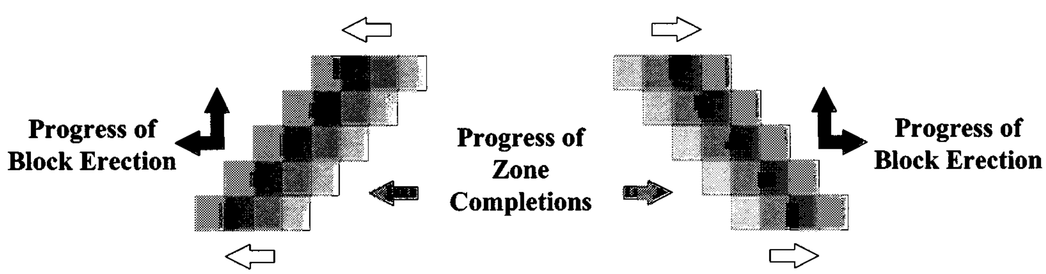
Ideally the work content and manning levels are balanced so that each zone stage completes at the same time allowing the following team to follow in equal steps, as shown in the adjacent diagram.



Applying Staged Zone Completion to a Vessel

Typically, the flow of the 'rolling wave' of zone-by-stage completions will follow a pattern similar to that shown below. Effectively achieving this depends on the block erection sequence and the configuration of the zones.

Onboard Rolling Waves



Typical Flow of the Stages of Zone Completion

Figure 5.1

Zone-by-stage Ship Completion

5.2 Erection join-up process flow

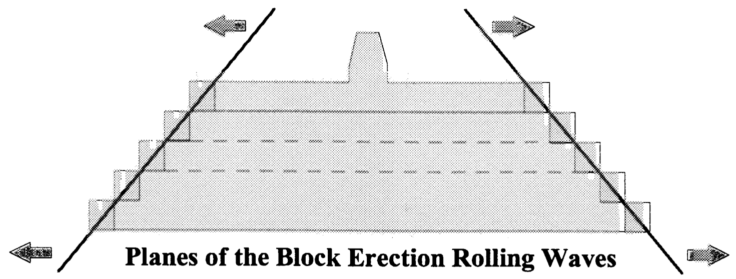
Developing work process flows for erection joints is usually overlooked and not given the level of effort deserved. Erection joints are the major link between shop assembly and system completion of the ship. Shipyards often focus on structural connections with little regard to the outfit. With an integrated approach all the interim products must be considered equally, this requires that the block breakdown for a vessel optimizes the erection work content of all systems. Without due care and expertise this can result in a conflict between optimum block configuration and optimum erection joint work content, which must be justified in the context of an overall reduction in man-hours and cycle time.

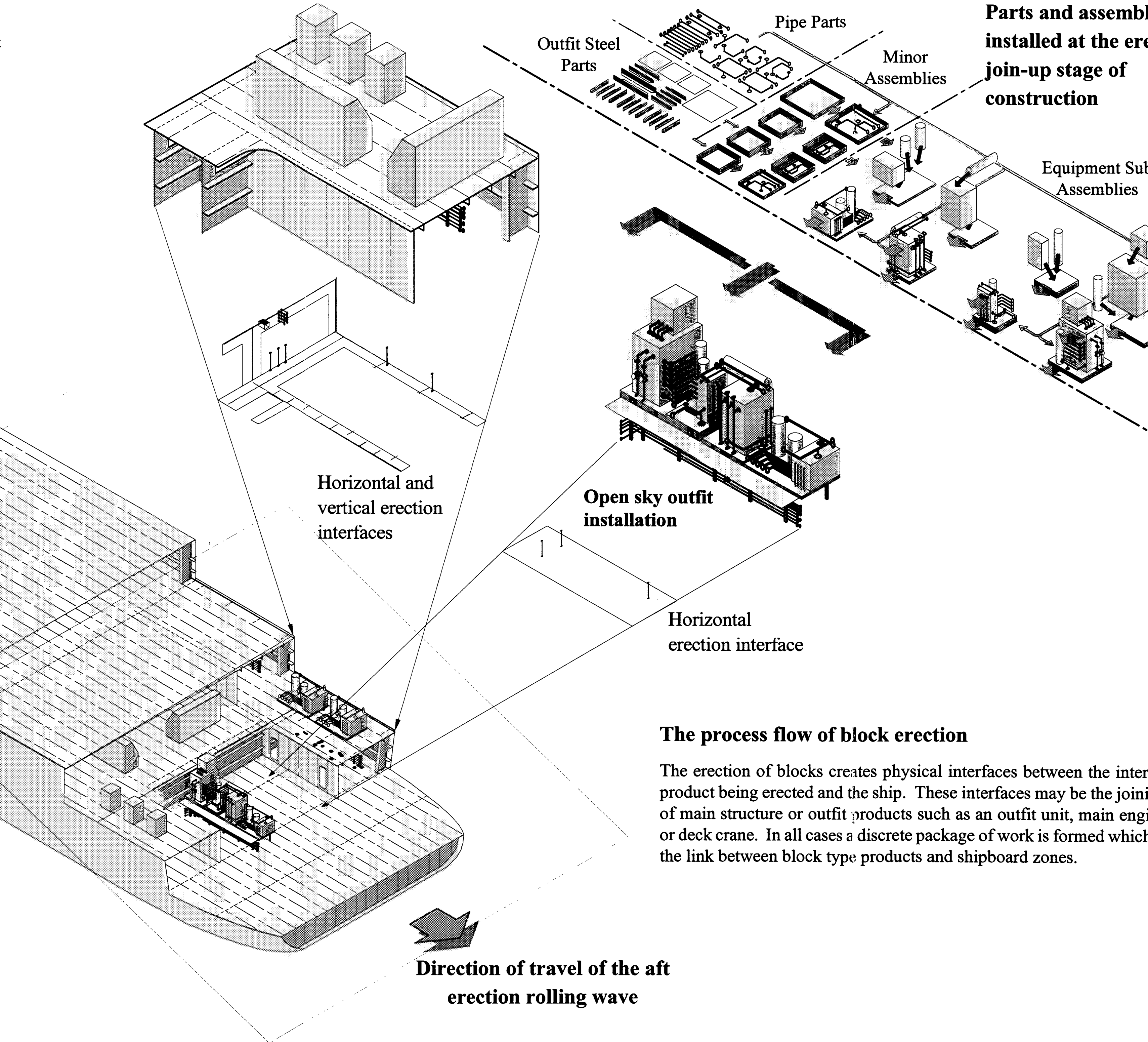
At erection, the interim products are the interfaces between the blocks, as shown in Figure 5.2. They are not only structural interfaces but also include outfit unit interfaces and outfit system connections. The level of outfit work content at erection generally depends on the type of product s being joined. Some erection joints will have high levels of outfit work such as those in the machinery and accommodation zones, others will have considerably less such as those in the cargo zones. The process for the completion of outfit work at erection follows the same stages of outfit described earlier, although in some cases the workpackages may become relatively small enabling all the stages of outfit to be completed by a single multi-skilled work team. Erection interfaces can require a wide variety of parts and assemblies, as far as possible, these should be confined to parts which are easily handled.

The erection stage is the transition between the block and shipboard zone stages of construction and it is important to recognize that the erection 'workstation' is equally transitional in that manning, tools and materials must be easily transferable to other locations. In all other aspects the erection interface workstation is the same as any other assembly workstation having facility and process constraints which define product attributes and consequently design criteria. It is important to understand that the erection workstation also requires specific workstation production information.

The 'rolling wave' of Block Erections

Ideally, the flow of the rolling wave of block erections follows a pattern similar to that shown below.





Process flow for the erection of blocks to the ship

Block erection is the transition between shop assembly and on-board completion. If planned effectively, it forms a rolling wave from the erection of the block through to the zone-by-stage completion of the vessel.

The process flow of block erection

The erection of blocks creates physical interfaces between the interim product being erected and the ship. These interfaces may be the joining of main structure or outfit products such as an outfit unit, main engine or deck crane. In all cases a discrete package of work is formed which is the link between block type products and shipboard zones.

Figure 5.2

Rolling Wave Erection and Zone Completion

5.3 Zone identification

Traditionally, zones were defined as compartments on the vessel. As their application expanded from a means of production management to the basis for all pre-production work organization and production and material control the principles for zone definition changed.

To fulfil the requirements of all pre-production and production functions the definition of shipboard zones must meet the following criteria:

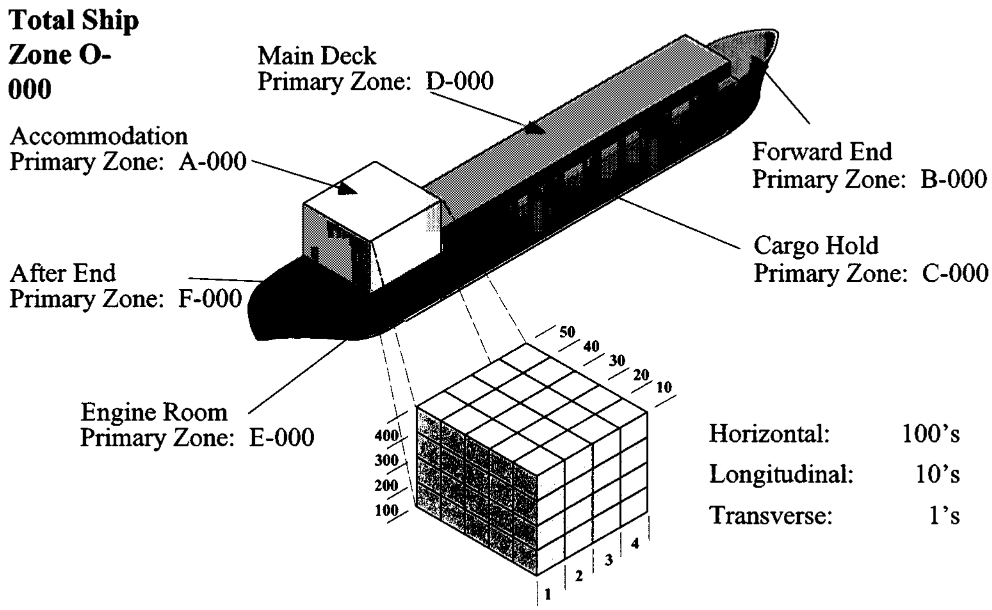
- They must be defined hierarchically. The zone for designing a ship system is not the same as the zone for installation workpackages.
- They must be flexible. The zone for installing pipework is not the same as that for pulling electrical cable.
- They must be of a size that workpackages for production stages are not too small so that the numbers become unmanageable, or so large that the manpower becomes unmanageable.

Figure 5.3 illustrates the principle for developing shipboard zones to meet the above criteria. At the highest level the whole ship can be defined as a zone say for the preparation of the basic design, erection, sea trials and hand-over documentation. At the lowest level a zone can be a single compartment or group of similar compartments.

The hierarchical and flexible definition of zones is achieved through the application of a meaningful coding system. Each number in the code refers to a hierarchical division of the zone. The introduction of a zero into the zone code changes the configuration and size of the zone. The illustration demonstrates the application of a four-character alphanumeric zone definition code.

This approach enables planning and production engineering to define 'working zones' that balance the outfit stage work content needed for the zone-by-stage completion of the ship. Thus, they are able to generate more appropriate packages of work. A typical example of this method of zone definition is given in the following section.

Principles of Primary Zone Coding



Principles of Secondary and Tertiary Zone Coding

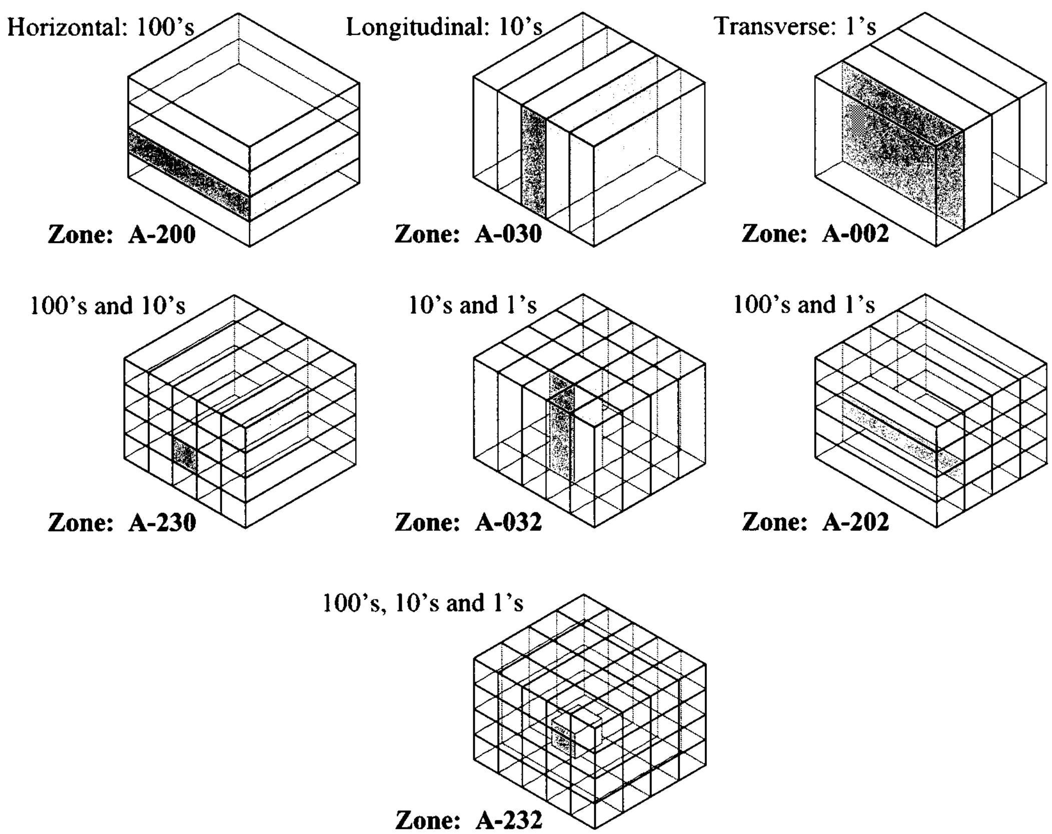


Figure 5.3

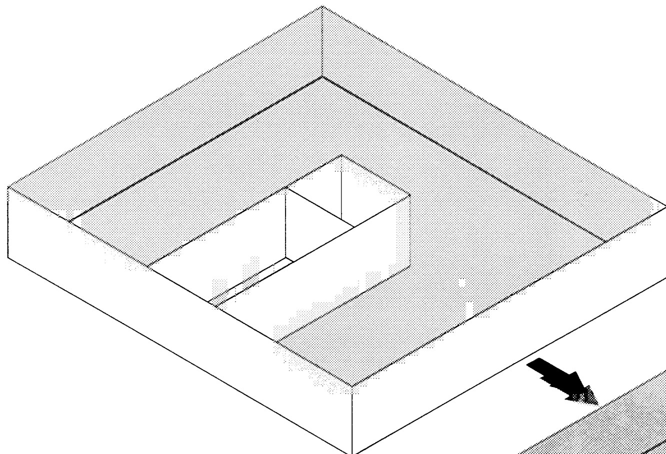
Flexible Zoning Methodology

5.4 On-board process flow

Depending upon the size of block a shipyard is capable of erecting, the level of on-board outfit work content can be either minimal or extensive. Also, as in the case of the erection joint stage, zonal workstations are transitional. The important factor is that planning and production engineering are able to readily define the stages of construction and relate the level of completion achieved during assembly to the extent of outfitting required to complete the on-board zone.

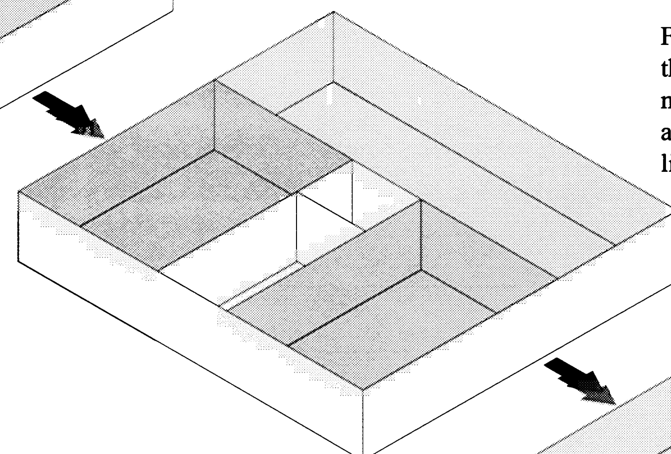
The example shown in Figure 5.4 is for a deck in an accommodation area where the 'flat pack' method is used for internal compartmentalization. In this case transient zones are created to match the type and stage of work. The first stage uses the whole deck level as a zone for completion of the major hotwork. That zone is then sub-divided into zones having approximately equal work content for minor hotwork. When completed, the zones are reconfigured for the erection of internal bulkheads in the outboard areas, leaving a central zone for the completion of the services, such as cabling and pipe installation. In the final configuration the outer zones remain the same for the installation of furniture and fittings while the central zone is further sub-divided for completion of the passageways and washroom.

This method of zoning is applicable to all zones of a ship, both internal and external. The basic breakdown of these 'working zones' is developed during the initial stages of the design process concurrently with the integrated block breakdown. This early zone definition is essential, as it is the basis for all pre-production and production work organization and control.



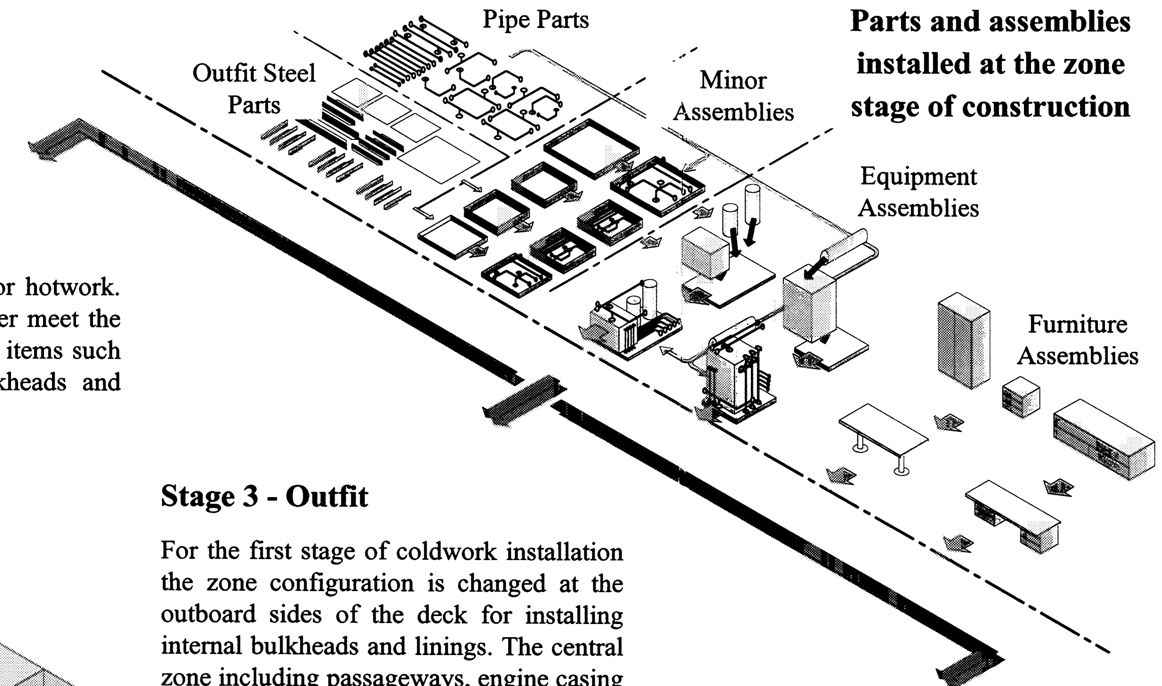
Stage 1 - Outfit

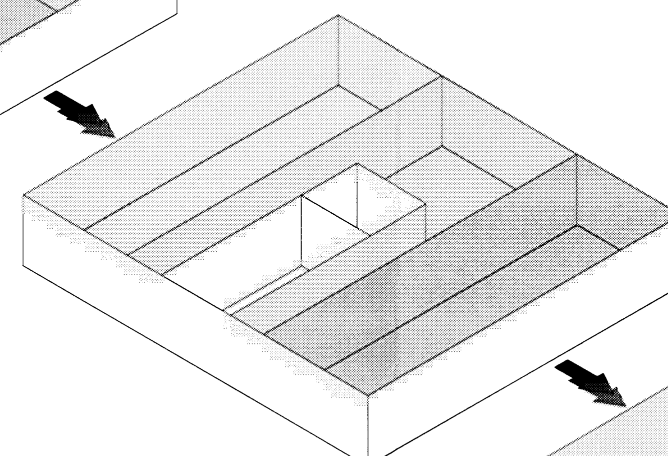
Immediately after the block erection joint which closes out a zone is complete the first stage of major outfit hotwork begins. This typically includes items such as, watertight doors, windows, etc. In this case the zone is an entire deck of the accommodation area.



Stage 2 - Outfit

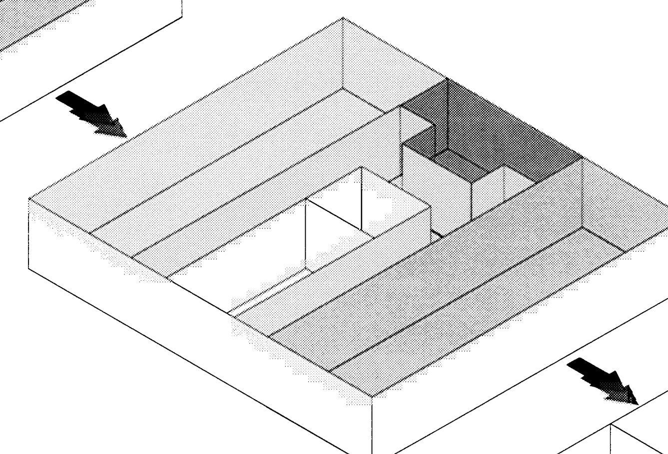
Following completion of the major hotwork. the zones are reconfigured to better meet the needs of installing minor hotwork items such as the grounds for internal bulkheads and linings.





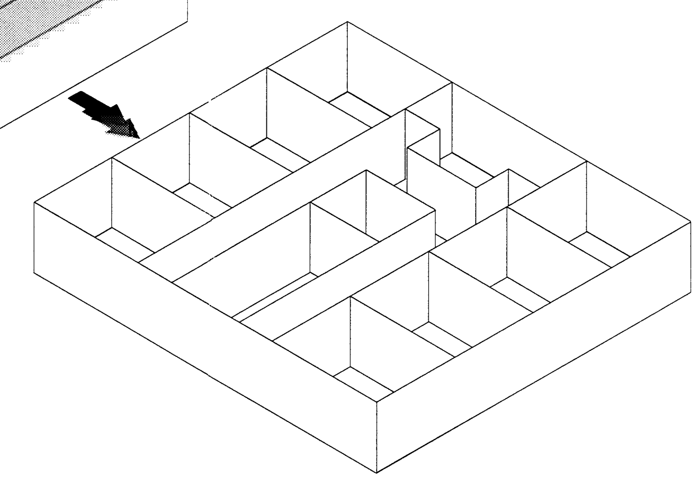
Stage 3 - Outfit

For the first stage of coldwork installation the zone configuration is changed at the outboard sides of the deck for installing internal bulkheads and linings. The central zone including passageways, engine casing and stairwell remains the same for installing cabling and other services to be fitted.



Stage 4 - Outfit

The configuration of the outboard zones remains the same as stage 3 for installing furniture, fittings, carpets etc. The central zone around the engine casing and stairwell is reconfigured for passageway and washroom completion.



Stage 5 - Outfit

The final zone configuration reverts to the entire deck for vessel handover. At this stage loose items such as chairs, mattresses, curtains, bed linen, portable electrical equipment and other items prone to easy damage and theft are installed.

The process flow of on-board outfitting

Applying an integrated construction approach means that the majority of outfitting is installed during the assembly stages. However, in some cases such as an accommodation area it may not be possible to complete the outfitting of the decks prior to erection and consequently there could be a considerable amount of on-board work.

Unlike the earlier stages of construction on-board completion does not have fixed workstations. The work flows in a rolling wave through transitory workstations in a zone-by-stage completion.

Shipboard zones do not need to be of fixed sizes and configurations. They should be flexible so that they can adapt to the stage of completion and the type of work being carried out.

The figure illustrates the onboard completion of an accommodation deck and demonstrates the application of a flexible zoning methodology. The methodology is equally applicable to all internal and external zones.

It should be noted that the approach to zone definition and completion is not necessarily confined to shipboard work. If a complete zone becomes available at the block or grand block assembly stages then the same approach is applied at those stages and the zone can either be completed prior to or after erection.

Figure 5.4

Typical Zone-by-stage Completion of an Accommodation Deck

NATIONAL STEEL AND SHIPBUILDING COMPANY

NSRP PROJECT 8-98-2

Process Modeling to Improve Productivity of On-Board and On-Block Outfitting

Task 4 Deliverable

Perform Comparative Analysis between NASSCO Current and World-Class Outfit Production Process Activities

FIRST MARINE INTERNATIONAL LIMITED

March 1999

Perform comparative analysis between NASSCO current and world-class outfit production process activities

CONTENTS

1 INTRODUCTION

This document forms part of the NSRP Project 8-98-2, Process Modeling to Improve Productivity of On-Board and On-Block Outfitting. The primary objective of the project is to establish a world-class methodology for the definition of outfit interim products, which can be competitively assembled and installed on a vessel in a multi-trade work environment. The development of a hierarchy of outfit interim products, which can be integrated with the steel structure at the optimum time in the assembly process, will significantly improve the performance of on-block and on- board vessel outfitting.

The objective of this document is to summarize the major differences between NASSCO's current and world-class outfit production process activities. The analysis compares interim product structures and the assembly and installation processes. It identifies principal variances in the approach to developing an interim product structure, and highlights shortcomings in the organization structure, facilities and operations, which need to be addressed in order to achieve world-class status. Where required, the analysis examines key activities in the pre-production and production support functions, particularly those relating to the application of an interim product structure.

The results of the comparison are summarized in a series of performance improvement recommendations contained in Section 4 of the document.

2 COMPARATIVE ANALYSIS OF NASSCO CURRENT AND WORLD-CLASS

In recent years NASSCO has made considerable progress in improving their performance in ship outfitting. This improvement is leading towards achieving a level of performance, which will be competitive in international commercial shipbuilding. The implementation of on-block and on-unit outfitting techniques, together with the development of workstation-style production information and the introduction of multi-skilled work teams has significantly reduced the outfit production man-hours and cycle time. This improvement has been achieved through a wide variety of highly focused production oriented projects. In support of this project, NASSCO is building on these achievements to create a firm foundation of performance which is necessary in achieving international competitiveness.

A recent project, funded under the Maritech program, developed an overall methodology for a product-oriented approach to outfit design and production based on a 'ship factory' concept. This has provided the necessary structure and cohesion by which future projects can be organized and managed for maximum benefit. The company realizes that they still need to further improve performance if they are to achieve competitiveness in the international commercial shipbuilding market.

The following sections compare current outfit production process activities to those required to implement a world-class, product-oriented, ship factory. The following deliverables should be read in conjunction with this document:

- Task 2 Deliverable – NASSCO Current Outfit Production Process Activities, and
- Task 3 Deliverable – World-Class Outfit Production Process Activities.

The above documents are the basis for the comparison contained in the following sections and should be read in conjunction with this document. The topics selected for comparison are considered to be those which are fundamental to the successful implementation of a product-oriented approach to outfit design and construction. They include:

- the definition of outfit interim products and a hierarchical assembly structure for integrated production processes,
- the identification of the outfit on-block and on-board production processes including vessel hand-over,
- the identification of necessary production support information for all stages of the process, and

- the structure of the production support functions necessary to ensure successful implementation of a ship factory concept.

2.1 Outfit interim products

The ability to define a range of products that are outputs from a stable production process and can be combined hierarchically to form a wide variety of end products is a fundamental requirement for a product oriented approach. Previous projects at NASSCO have successfully defined and rationalized outfit products and product families at the part fabrication and unit assembly stages of construction.

However, there has been little attempt at defining intermediate levels of assemblies. In general, this is the result of a traditional approach to outfitting whereby outfit parts are either installed on the structural steel block or assembled into outfit units for installation. Consequently, outfit assembly facilities are limited and there has been no requirement for a hierarchical approach and the definition of applicable interim products.

Recently a number of projects have successfully integrated outfit parts and units into the steel structure. While this has resulted in significant savings in cost and time the lack of intermediate levels of outfit assemblies still provides further opportunities for the simplification of the assembly process and considerable performance improvement, as shown in Figure 2.1.

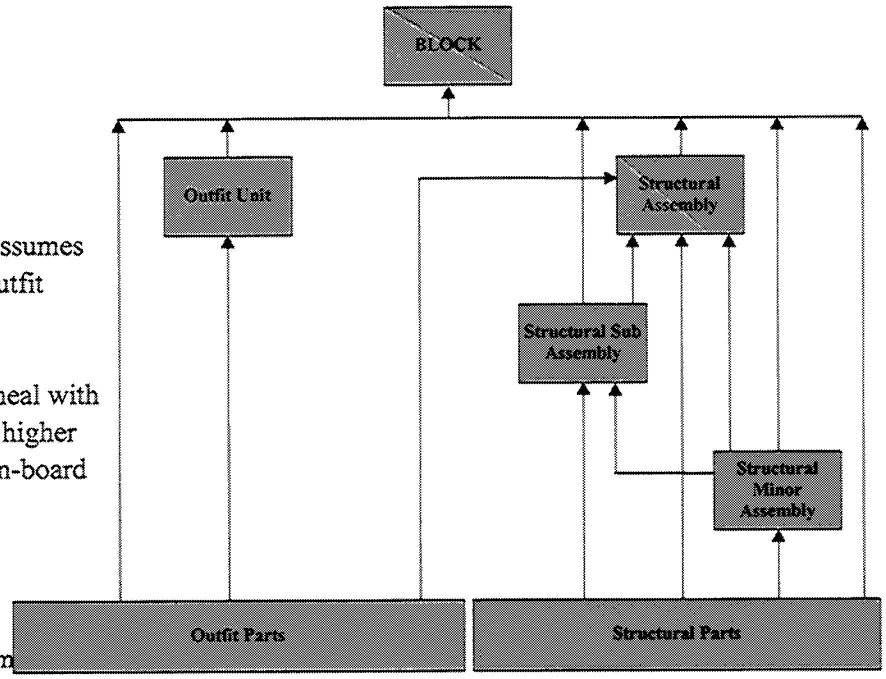
For some time the assembly of steel structure has applied a hierarchical assembly approach. Assembly of outfitting products is moving towards a similar approach. This has been a slow process due to the wide a range of outfitting materials and the number of individual product types that need to be combined into a series of repeatable assemblies. In addition, it has been a difficult process to come to agreement with all organizations involved as to what criteria determine an outfit interim product. What is required is a comprehensive catalog of all interim products, both steel and outfit, in a format that makes it immediately obvious to the user what a particular product type looks like and what the general production constraints and design criteria are. In this respect, it is extremely important that the catalog of interim products includes graphical and or pictorial examples of each product and product family. Thus, creating a product family album.

In addition to graphically illustrating the interim product structure the product family album must also show the sequence of assembly. This must show all product types and how they are integrated at all stages of construction. An effective method of showing this is to use a family tree diagram similar to that shown in Figure 2.1. The interim product families form the basis for developing production

Current Hierarchy

The methodology generally assumes that there is no hierarchical outfit interim product structure.

Outfitting tends to be piece-meal with outfit piece-parts fitted at the higher level on-block, on-unit and on-board assembly stages.



Indicates structural interim product volume

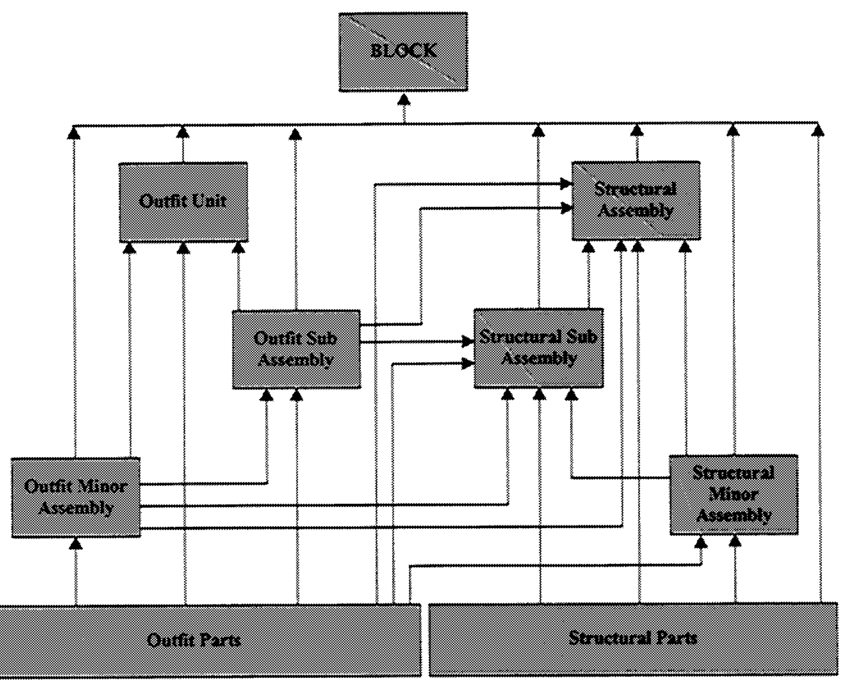
Indicates outfit interim product volume

Current Interim Product Structure

Integrated Hierarchy

The product structure has a wider range and variety of interim products covering structure and outfit assemblies.

It is a fully integrated product-oriented structure that ensures optimum integration of interim products throughout the assembly stages.



World-Class Interim Product Structure

Figure 2.1

Comparison of Product Structures for the Block Assembly stage

process lanes and assembly workstations as described in the task 3 deliverable, 'World-Class Outfit Production Process Activities'

2.2 Production processes and workstation definition

In a world-class production environment the definition of interim products and production process criteria is carried out concurrently. This ensures that interim products defined during the design and engineering phases are automatically cost effective to produce. Therefore, it is extremely important to clearly define and document each production stage, the associated processes and workstations, and the format and content of the required production information. This information is essential for the design and engineering functions to develop workstation-specific information.

Outfit production process at NASSCO are developing towards a workstation-type operation. Although the information was largely inconsistent and incomplete prior to the ISO 9001 certification, great strides have been taken to resolves these issues. As a result, the production and engineering departments have implemented projects to ensure full formal documentation is in place. This documentation describes the production processes, workstation attributes and facility constraints to enable the development of guidelines and decision-making criteria for the design and engineering functions. These are also updated and revised as process improvements are implemented.

2.2.1 Outfit assembly process

A combination of traditional advanced-outfitting technology and isolated outfit manufacturing facilities has not been conducive to realizing the benefit of a well-defined outfit interim product hierarchy. Emphasis has been on developing the efficient combining of outfit with structural steel blocks in the form of parts. Even where outfit units that have been designed, these are generally constructed by fitting individual outfit parts and equipment to a steel framework.

The main outfit assembly work area is adjacent to the building berth and is dedicated to on-block outfitting. Although this has enabled the majority of advanced outfitting work to be centralized, limited facilities and a lack of specialized equipment means relying on sharing key resources with ship erection. Also, because this activity is in an area primarily used for pre-erection storage the development of a purpose built outfitting facility, such as those in a world-class shipyard, is not practical.

The use of advanced outfitting techniques as opposed to product oriented processes means that there are few intermediate levels of outfit assemblies produced. Those that are, are generally assembled in

the outfit manufacturing facilities or are bought-in from sub contractors. Therefore, a move to product oriented production will necessitate a degree of facility development. This does not mean a major facility development program needs to be implemented as a first step. In the initial phase, temporary process lanes and workstations can be established in order to develop practical experience in product-oriented design and production, as shown in Figure 2.2. Simultaneously, the impact on cycle time and area requirement for advanced outfitting can be reassessed and an outfit facility development program prepared.

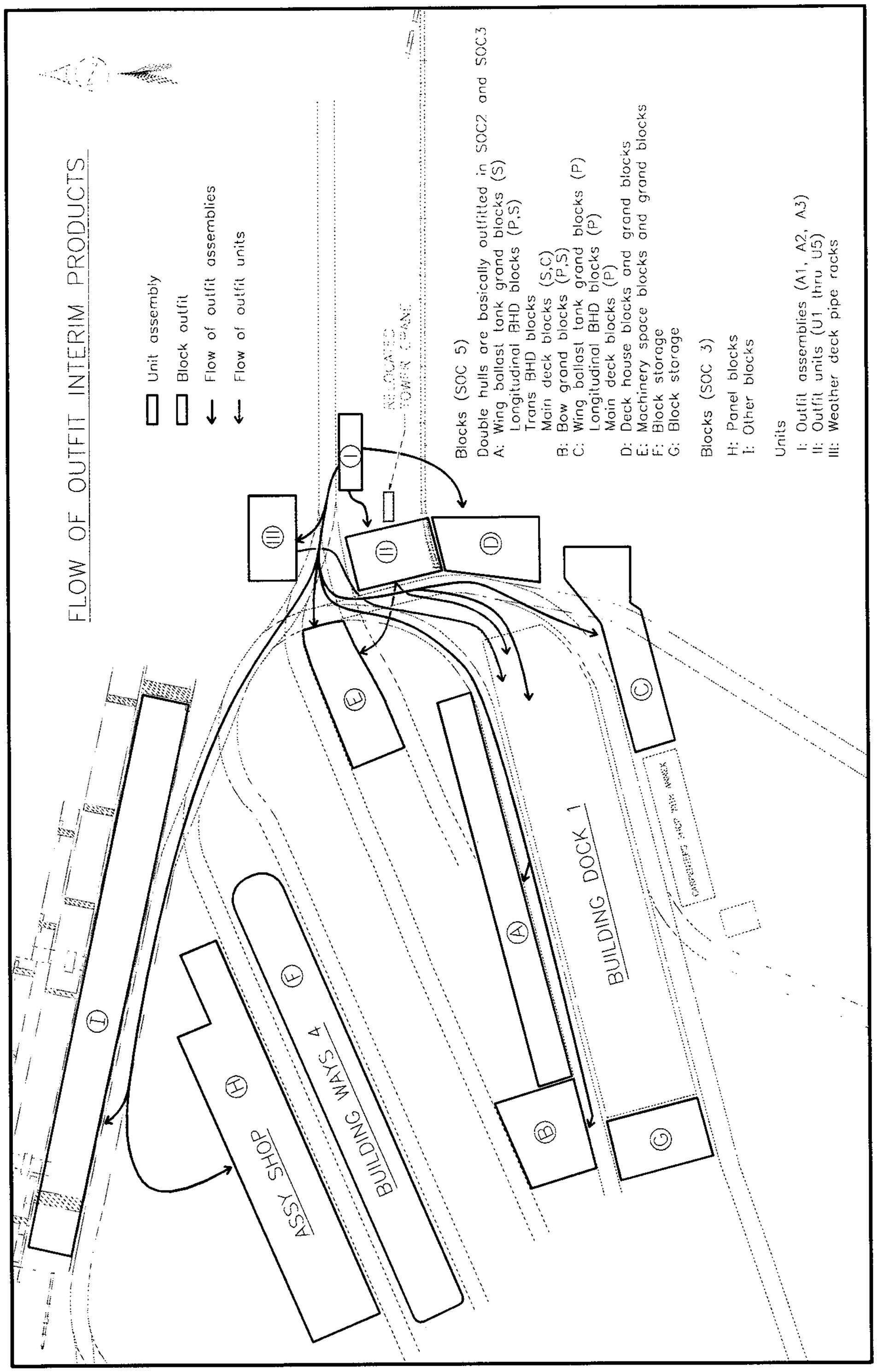


Fig 2.2
Flow of outfit interim products within the existing facilities

2.2.2 Outfit installation process

Traditionally, there is a poor definition of the work remaining on-board a vessel after erection and launch. The major planning and engineering effort being focused on assembly and erection. However, on-board completion is often one of the most time consuming stages of construction and the efficient organization is a major factor influencing overall cost and production cycle time.

Recent changes to the approach and organization of on-board work at NASSCO have moved towards implementing the 'rolling wave' principle incorporating multi-disciplined work teams as described in deliverable 3. While this is having a positive effect, the excessive block erection and join-up time together with ill defined stages of outfit, levels of work content and a lack of workstation specific information are resulting in unacceptable levels of work interruption and subsequent high levels of work-in-progress.

Clearly, the introduction of multi-trade work teams is beneficial however, the lack of dedicated on-board workstation information is seriously affecting performance. In the future, it is important that the onboard 'transient' workstations be treated like any other production process with dedicated information packages, including process engineering, clearly defined stages of completion and workstation specific information.

2.3 Format and content of production information

Current initiatives are examining the implication of multi-trade work teams on the format and content of production information. Consequently, the development of production information is undergoing review and change. Until recently the format and content of the outfit design and production information generally followed a traditional system-based approach. This involved the outfit planning and production engineering department interpreting the engineering output into a format more readily usable by production for advanced outfitting. However, the information issued to production remained system based rather than multi-system by stage and the interpretation was undertaken after the engineering effort rather than being an integral part. This had the effect of increasing the lead-time and cost for the development of production information.

The ship factory concept dictates that production information is specific to the workstation executing the work and is complete. Therefore, the move to a product oriented production environment will require significant change in the format and content of production information and the organization of the pre-production functions.

2.4 Pre-production and production support functions.

A number of development studies are being carried out in the various pre-production departments. In the majority of cases these focus on improving the performance of individual departments through the introduction of new systems, improved information flow and the reduction of duplication of effort. Overall, they do not form part of an overall coherent strategy to fundamentally change outfitting technology. However, these developments are beginning to effect change in the pre-production functions and there is an increasing appreciation of the benefits of a fully integrated pre-production organization.

Possibly the most significant current development is the organization of engineering teams by primary zone. At present this is being done within the traditional steel and outfit division. Consequently, achieving a fully integrated engineering process may still be some way off.

Clearly, recent projects aimed at developing the application of product-oriented design and production are initiating change. However, the full implications are still being internalized and a high level 'management of change' organization needs to be established. In a product-oriented environment, the design and engineering functions are directly accountable for production performance. Therefore, the development of an interim product structure is essential.

Elimination of the duplication of effort in pre-production activities has a major impact on the organization. In a traditional organization there are a number of departments that perform interpretation functions. That is, they transform information from one department into a form directly usable by others. Typical examples of this are the estimating, planning and production engineering functions. Integrated system technology together with a reorganization of the design and engineering functions can dramatically reduce the man-hours and time taken to perform these activities.

The tools used in the pre-production process are a major influence in reducing costs. The CALMA outfit engineering software system currently being used at NASSCO is old and susceptible to regular breakdown. It is also difficult to interface with the TRIBON system used for steelwork. Interfacing of multi systems increases the potential for error, delays the transferring of information and increases duplication of effort. In future the full benefits of integrating the pre-production organization will only be realized by integrating the computerized systems.

3 IMPROVING PERFORMANCE

Following are a series of recommendations that will assist in improving outfitting performance. The key to achieving improvement is a structured approach to developing the elements required for the implementation of a product–oriented philosophy and a factory-style concept for production operations

The development of a company shipbuilding strategy is an essential first step in the performance improvement process. It provides the design and engineering functions with a solid base for producing practical, cost effective, repeatable products. The key elements required for the development of a shipbuilding strategy are shown in Figure 3.1. This is not necessarily a major undertaking, much of the basics can be developed during the current SLNC program and ongoing performance improvement initiatives. However, neither should it be regarded as a short-term activity, it will take time to develop a comprehensive shipbuilding strategy. However, major savings can be realized in an initial implementation on the next new contract provided the main structure of the strategy is in place and relevant pilot projects have been undertaken to develop experience.

The suggested performance improvement initiatives described in the following sections, fall into the three main categories of short-term, medium-term and long-term and are all aimed at maximizing benefits at each level of technology implementation. Projects initiated in each category would have the principle objectives of:

- developing product oriented design and production operations,
- adding to the formalization of the company shipbuilding strategy, and
- impacting performance on current or planned shipyard contracts.

Short term projects - where savings in man-hours and time can be realized on the current SLNC program. These would be highly focused, within a single tertiary zone or interim product, so that major re-design or re-engineering is avoided.

Medium term projects - where savings in manhours and time can be realized on a new vessel design and a reorganization of the design process will enable a significant shift to a product-oriented concept.

Long term projects - where savings in manhours and time can be realized through the development of operations strategies, facilities or integrated computerized systems.

The above categories do not reflect a priority for initiating projects. They represent a judgement of the project development time and pay back period. Each improvement project must be an integral part of

realizing a product oriented work environment and therefore it is essential to establish a 'management of change' organization before initiating any projects.

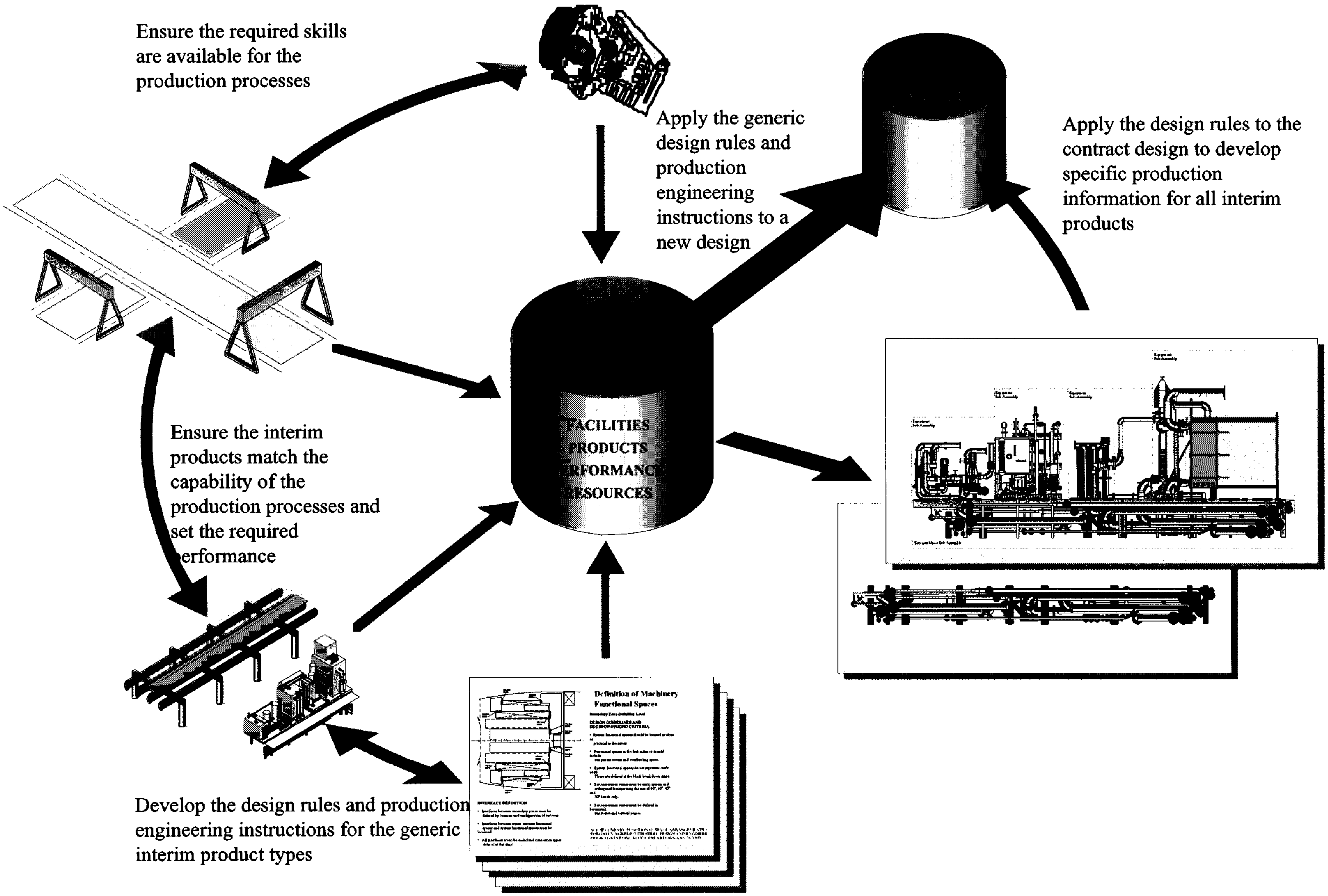


Figure 3.1

Elements required to improve performance

3.1 Outfit interim products

As stated previously, a common understanding of what constitutes an interim product is a major factor affecting the development of a product-oriented concept. Therefore, the preparation of a pictorial catalog of interim products, developed within a logical hierarchical structure, is the most important step in starting the overall transformation process. It allows all those involved in the ship construction process, to see what a product-oriented philosophy actually looks like.

The main benefits of creating an interim product catalog are in that it enables designers and engineers to readily recognize products, which could be identical or similar in form to be repeatable parts and assemblies. Too often, the opportunity to save time and effort in the pre-production process is lost because there is no practical 'design for production' reference in place to provide applicable product criteria at each stage in the overall design process. Hence, designers and engineers waste time generating individual products when they should be identifying and creating 'repeatable' interim products.

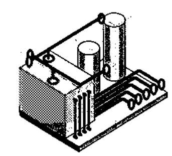
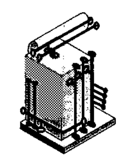
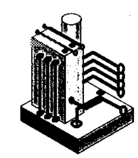
3.1.1 Identifying outfit interim products

In order to create a useable tool describing all of the company's interim products, it is recommended that a pictorial interim product catalog or 'family album' be produced similar in structure to that shown in Figure 3.2. This format combines a graphical representation of each product family with a simple code to identify the interim product so that products of similar work type can be readily identified during the product analysis process, as described in the following section.

Furthermore, it should be noted that outfit interim products are not limited to the pre-erection assembly stages, but include the onboard installation stages of zone completion. This fact is important in developing a consistent approach to creating a product-oriented design and build methodology. Often, shipyards miss repeatability opportunities by not appreciating that lower level interim products are common across all primary zones and stages of construction.

A more detailed description of the process for developing an interim product structure applicable across all ship zones is described in the task 3 deliverable - World-Class Outfit Production Process Activities".

The importance of examining both the pre-erection and on-board work stages is described in the following sections.

Product Type Reference			Maximum Size & Weight		Graphical representation of the Product Family			
Production Stage	Product Type	Product Family						
C	3	a	Length	20 ft				additional product family members
			Width	10 ft				
			Height	5 ft				
			Weight	2.75 t				

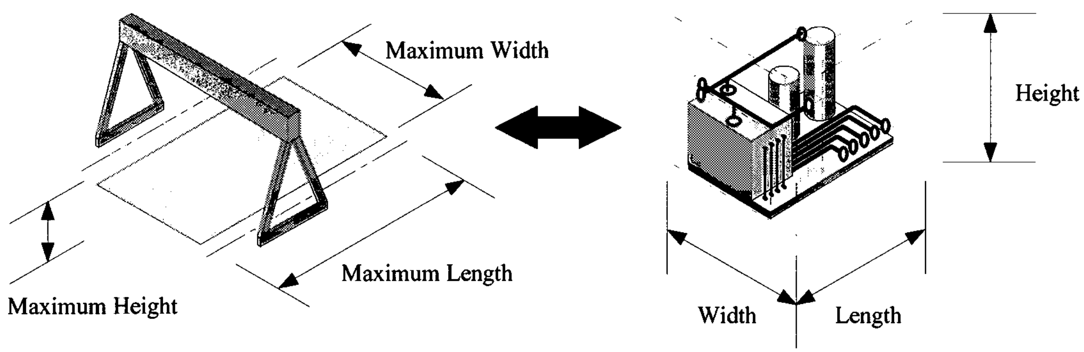
Code identifying product types

Limits imposed by the workstation

Pictorial representation of each member of the product family.

Process Lane / Workstation for Products Type C3

Product Type C3a



Maximum Lifting Capacity (Product Weight)

Product Weight

Product Family Album

Above is a typical format for an interim product family album. Its purpose is to show all potential configurations of a family of products.

Process lane constraints and production attributes are also included in the family album and may be linked to the product type by the coding system.

Figure 3.2

Developing the Interim Products Family Album

3.1.2 Outfit product analysis

Having developed the means of identifying interim products, the next step is to determine the quantity of products required in the company product range. A method of doing this is shown in Figure 3.3. This, together with the annual vessel throughput, will determine the outfit workstation loading. Interim product throughput requirement is the first check on the capability of the current facilities to handle a projected workload. It is extremely unlikely that a company implementing a product-oriented approach for the first time will have the correct combination of outfit workstations. This aspect of facility development and organization is discussed in a later section.

The approach to product analysis is to examine each vessel in the product range and estimate the number of major interim product types in each primary zone using the interim product family album. For each major product type an interim product hierarchy diagram and product analysis sketch is prepared to approximately determine the numbers of lower level interim products and assembly sequence. When summarized for all major product types in the yard product range this provides a good approximation of the interim product volumes.

Where information for a particular vessel type is incomplete or not available factors of complexity can be established using a known vessel. The interim product volumes are then calculated on a basis of comparative complexity. To estimate the annual throughput requirement, likely combinations of vessels are analyzed to determine the impact on interim product volumes and consequently the variation in workstation loading.

3.2 The outfit product assembly process

Implementing integrated, product-oriented production processes in a shipyard is a major change in philosophy from the traditional system oriented organization and an important step in a company's ability to sustain continuous performance improvement. To maximize the benefits during the transition period the implementation must form part of a structured product and process change strategy. That is, developing the product structure must be carried out in conjunction with the production process analysis and development. Imposing current production constraints, operations and organization will considerably restrict the potential of product oriented production.

The development of the interim product catalog and product analysis enables the definition of optimum production processes and workstations. These can be compared with the existing processes and gaps and imbalances identified. Knowing the shortfalls of the existing facilities enables the preparation of

logical plans for short, medium and long-term process and facility development. Prioritizing developments can be done by examining the projected order book and interim product volume requirements.

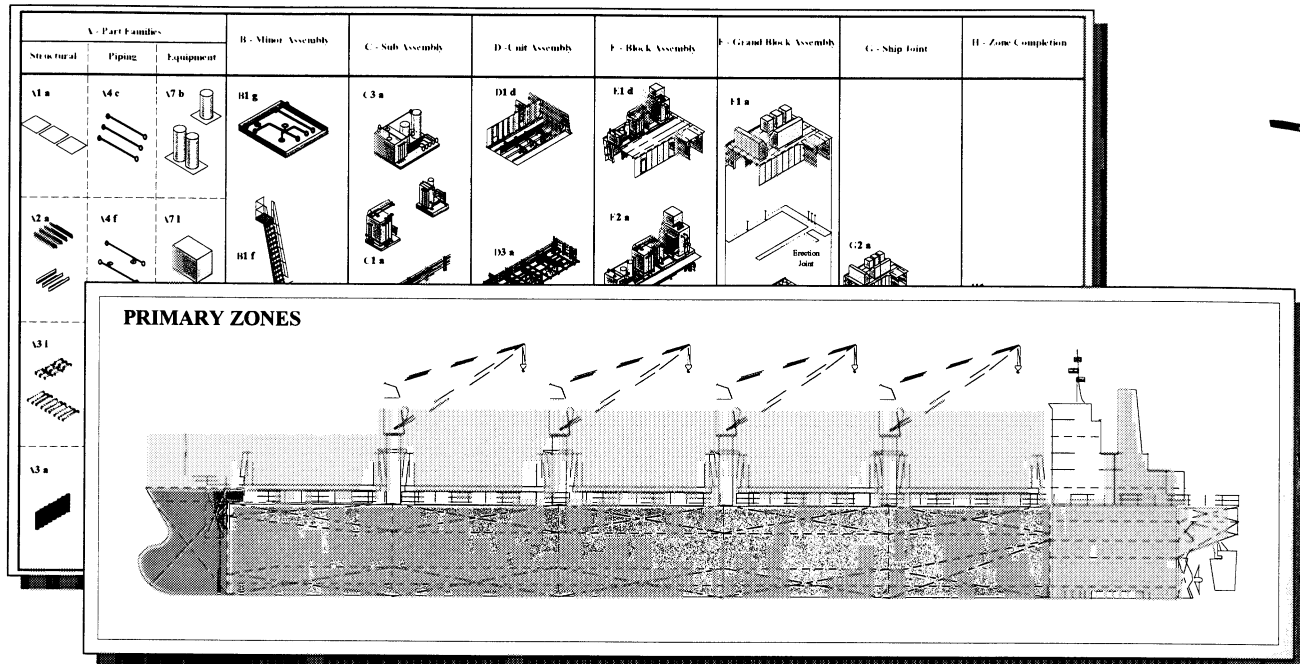
It is important to remember that any process development plan must consider the impact on previous and subsequent activities. This is particularly relevant in the case of pre-erection and post erection processes.

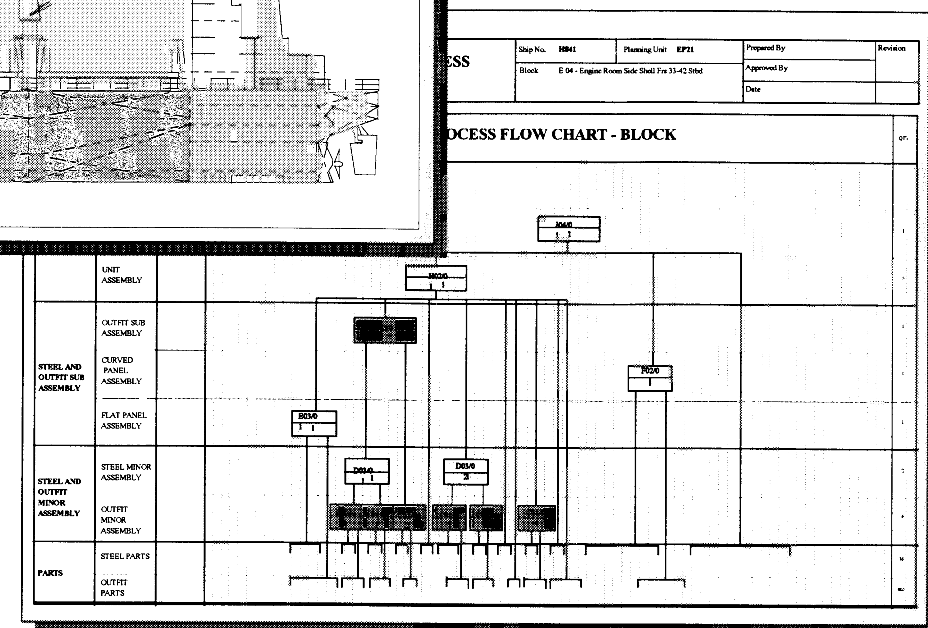
Analysis of Outfit Interim Products

In order to determine the size of production process lanes it is necessary to quantify the annual outfit interim product throughput requirement. This requires an interim product analysis of all the vessels in the company's product range.

Where vessel information is not available or is limited then the numbers of interim products can be estimated by applying a factor of complexity to a known vessel. The annual interim product throughput requirement is then determined by examining various combinations of vessels.

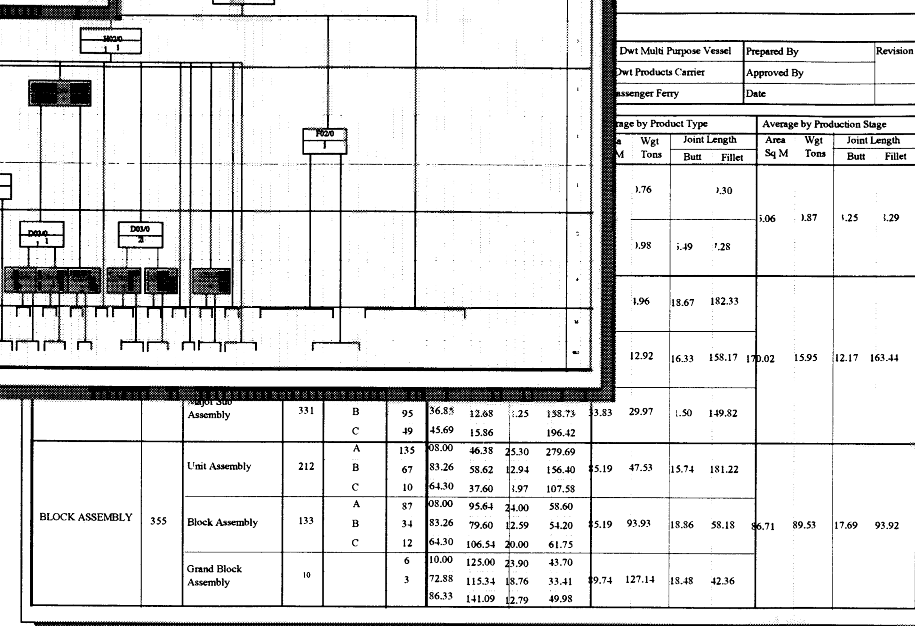
The interim product quantities developed in the initial stage will be approximate, based upon generic family types. However, these will be refined as the interim product families are applied to individual contracts.





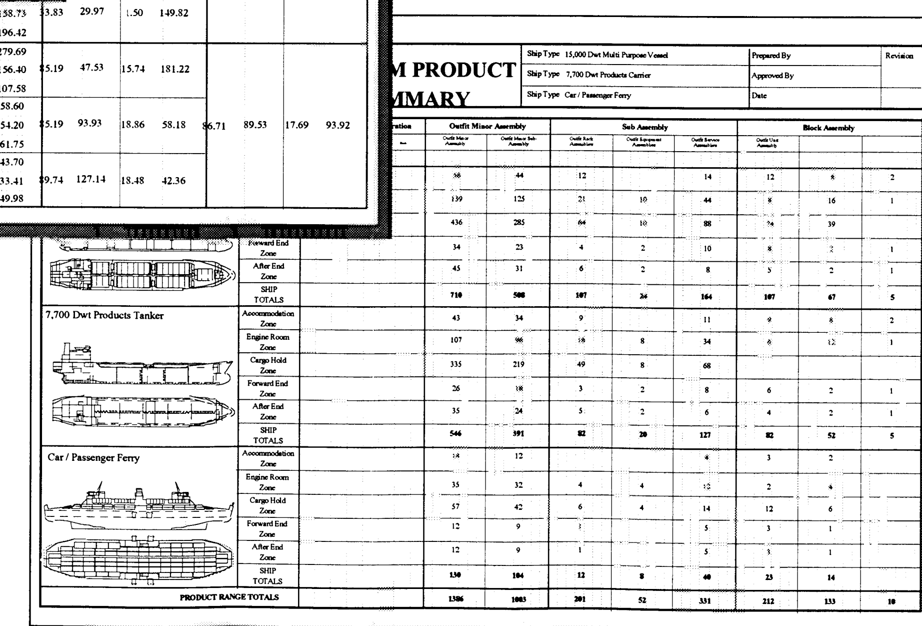
Step 2 - Interim Product Analysis

Once the major interim types are quantified. The lower levels of interim products such as, assemblies, sub-assemblies and minor assemblies are identified and individual hierarchical product charts are developed for each interim product. This is done in as much detail as possible.



Step 1 - Interim Product Quantification

Identify the quantities of each major type of outfit interim product as shown in the product family album for each primary zone of the vessel. This includes outfit, structural, joints and on-board zones. At this stage initial quantities of all major products needs to be established, these are refined as the ship definition process develops.



Step 3 - Interim Product Summary

When the product analysis is completed for each ship type, the results are summarized across the yard product range. This summary assists with developing the workstation loading and design for various product mixes.

Figure 3.3

Methodology for analyzing the range of interim products

3.2.1 The pre-erection outfit assembly process

Assembly processes are usually the initial targets for development when considering a change in methodology. They are the most obvious and development projects can be confined to relatively small areas of the shipyard. The product analysis and definition of product families through the application of group technology enables the development of generic process lanes for each family. These establish the basis for comparison with existing facilities.

In some instances it may be found that the existing facilities are either inadequate for a product assembly process or are inconveniently situated. An analysis of the product volume requirement will assist in determining which product lanes are given development priority. As mentioned earlier, it is not necessary to invest in highly sophisticated assembly process lanes as a first step. In the initial stage of process change it is sometimes better to establish temporary process lanes with static workstations using largely manual assembly methods.

This will have the advantage of providing practical experience in product-oriented assembly with minimum capital investment. The use of temporary workstations will also be beneficial in refining the requirements for future permanent facility development and defining the workstation information requirements.

3.2.2 The post-erection outfit installation process

Unlike the pre-erection assembly processes there are no fixed easily identifiable workstations for on-board zone completion. Workstations are transitory, with work flowing in a series of installation stages along a 'rolling wave' following the block erection.

It is important to note that on-board zone completion includes a wide variety of product types that can have conflicting spatial requirements such as, painting, insulation, joiner work, cabling etc., These varying products tend to require different zone configurations for efficient installation and control. It is therefore extremely important that the on-board installation process is well defined, as described in the task 3 deliverable – 'World-Class Outfit Production Process Activities'.

As with the assembly processes, it is recommended that generic on-board installation processes are clearly defined and documented for each primary zone, similar to the assembly interim product catalogue. This provides guidelines and decision-making criteria for the development of zone completion workstation information.

3.3 Development of work instructions

Product-oriented production requires workstation specific production information. Workstation information should be developed for both pre-production and production workstations. It is essential to consider the pre-production processes in a similar process lane and workstation context as the production processes. The following sections describe the principal guidelines for developing a workstation approach for the preparation of design and production information.

3.3.1 Definition of the design guidance information

Work instructions for the functional design stage must support the main objectives of the design process, namely to meet the functional requirements of the vessel and to ensure that the vessel can be produced at a competitive and profitable cost in the shipyard.

Information critical to achieving the design objectives includes:

- a clear definition of the owners requirements (this means interpreting the owners specification into a set of unambiguous requirements),
- adequate and up-to-date vendor information edited to meet the requirements of each design stage,
- accurate, internally produced information, from previous contract stages, and
- a set of design for production requirement guidelines and decision-making criteria specific to each stage of the design process.

Combined, they form the definitive work instructions enabling designers and engineers to develop a vessel design, which meets the owner's requirements and is capable of being efficiently produced in the shipyard.

Design for production guidelines are often referred to as the 'design for production' manual. Unfortunately, this title is generally associated with the generic manuals developed for the U.S. industry during the 1980's. These manuals describe the concepts of designing for producibility. A 'design for production' manual is shipyard specific, as it must consider the constraints of the facility and process limitations, which are reflected in the interim product structure and encapsulated in the shipbuilding strategy.

3.3.2 Definition of production information

Once the interim product families together with their process engineering and production process attributes are established, the format and content of the workstation information can be defined. It must be remembered that workstation information is a combination of all the outputs from the various pre-production activities issued to the production departments for the execution of work on a vessel. It is essential that production workstation information contains only information relevant to the workstation, is consistent and complete, and does not contain duplicate instructions or information. Workstation information must not be subject to shop floor interpretation as to how, where and when to carry out the work.

The format and content of workstation information must be clearly defined for all of the following:

- parts manufacturing,
- pre-erection or shop assembly,
- erection and post erection (on-board) completion,
- system testing, at all applicable stages, and
- hand-over documentation.

Essentially, each of the above will have different information format and content to meet the requirements of the individual processes. It is important that each is considered separately and it is not assumed that a common format and content or size of drawing will be applicable in all cases.

The format and content of production information, has a significant impact on the organization and operations in the pre-production functions. In the initial transition to a product oriented methodology, existing CAD/Database systems may not be able to produce the production information packages in the required format. Therefore, it may be necessary to adopt temporary solutions. Simple, temporary solutions may include partial photocopying and cut and paste techniques. As with the use of temporary workstations in production, this approach enables refinement of the methodology and the ability to accurately specify what is required from future CAD/Database developments.

The format and content of workstation information is dynamic. As production processes develop, the interim product structure and the format and content of workstation information will need upgrading to reflect the improvements.

3.4 Shipyard core competencies

A major part of improving the company's performance involves developing the skills of the personnel. This applies equally to the pre-production and production workforce. Often, training of pre-production personnel in the fundamentals of product-oriented technology is limited or non existent. However, it is their understanding of the philosophy and how effectively they apply the interim product structure that directly influences the efficiency and profitability of the shipyard.

It is recommended that a series of training modules be developed for all shipyard disciplines to provide philosophical and practical training in the product-oriented approach as applicable to their work. This should include practical pilot projects covering design, engineering and construction of outfit interim products in various primary zones of the current production program. This will develop a common and consistent understanding of how product oriented production works. Training must take place prior to attempting a full-scale implementation on a new contract.

3.4.1 Pre-production personnel

As in production, there is a need to develop a greater level of steel/outfit integration in the design process. This can be achieved by developing multi-disciplined teams of designers and engineers for each primary zone of a ship. The skill content of the teams will depend upon the work content of the primary zone. Each team must be fully responsible and accountable for all information relative to the zone.

One method of work organization within the zone teams is to allocate responsibility by secondary zone. Each engineering section within the teams is then responsible for generating the model and extracting all the necessary production information, from part fabrication to zone completion. Each primary zone team is responsible for the preparation of vessel hand-over documentation.
This approach has major benefits in reducing pre-production errors, omissions and duplication of effort commonly experienced in a traditional system based organization. A major benefit of multi-disciplined design and engineering teams is that a natural cross-fertilization develops multi-skilled personnel.

Longer-term performance improvement can be gained by broadening the knowledge base of the individual team members. This may include teaching product-oriented methodology, developing and managing pilot projects, teaching CAD and Database systems and developing initiatives to improve team performance.

3.4.2 Production personnel

Expansion of the current NASSCO initiative of developing multi-skilled work teams has the potential to dramatically improve performance in all areas of production, particularly in a product oriented environment. At present multi-skilled teams have been successful in outfitting cargo blocks for the SLNC program. They have also started to be integrated with some of the other block type process lanes in the on-block area. Currently the ground work is being laid to phase the multi-skilled teams into the on-board processes.

In a product-oriented, ship factory environment, multi-skilled work teams are essential for the efficient operation of all workstations. In this way the pre-production and production organization are similar and there are corresponding responsibilities to ensure the completeness of the products. The matching of the pre-production and production organization and responsibilities promotes a closer and more effective working relationship. This effectively increases the team size, embracing both pre-production and production activities and tends to lead to the initiation of cross-functional performance improvement projects.

In this context it is extremely important to extend the implementation of multi-skill teams throughout the shipyard in both pre-erection and post erection operations. Initially, these teams will tend to be multi-trade, where personnel assist one another but remain within their own trade responsibility. In time and with relevant multi-skill training these trade teams will develop into multi-skill teams capable of operating efficiently and independent of trade supervision at their workstations. However, adoption of the product oriented, multi-skilled work team approach requires a very different organization structure to the system oriented, trade skill work team approach and this should be considered very carefully before randomly expanding the multi-skilled concept.

4 CONCLUSIONS

This project focuses on the requirements for building a solid foundation in order to implement a product-oriented, ship factory concept for ship outfitting. The key to realizing this is a solid understanding of product-oriented philosophy. This is achieved through the implementation of the elements described previously and the establishment of a 'management of change' organization to control the development and introduction of technology change. The timing of this change depends primarily on the:

- ability of company management and supervision to assimilate the new philosophy,
- timeliness of a new design and build contract, and
- availability of investment capital for training, pilot projects and facility development.

Although some factors are outside the company's direct control, such as when new contracts will be signed and to some extent, the timescale required to bring new facilities online, it is believed that the approach is practical and achievable. With a management of change organization to ensure that pilot projects are aimed at developing specific parts of the overall concept, opportunities on the current contracts should be taken advantage of. This will not only improve performance but will also provide valuable experience for a wider implementation on the next new contract.

4.1 Short-term improvements

Some improvements can be achieved almost immediately. However, the stage of current contracts, current facility constraints and more importantly, the ability of company personnel to learn and implement the new techniques will limit the extent of improvement. Clearly, the cost of the learning process will offset some of the overall savings but training is crucial to the longer-term success of implementing new technology.

The following short-term actions are recommended:

- develop an integrated interim product catalog,
- analyze the outfit interim product requirements across the company product range,
- define the generic production processes both ground based and on-board,
- compare the current production processes with the generic and develop short, medium and long-term plans to initiate process change,
- define the format and content of pre-production and production work instructions,

- develop the use of multi-skill teams in design / engineering and production and train the personnel through practical pilot projects, and
- begin the development of training modules.

The short-term actions can be initiated immediately and will help develop a solid foundation for a wider implementation on a new design

4.2 Medium-term improvements

It is anticipated that major performance improvements will be realized with the full implementation of the product-oriented, ship factory methodology on the design of new vessel. The extent of the methodology application will only be limited by the constraints of the existing facilities and computerized support systems.

Implementation on a new contract will require establishing assembly process lanes for the new range of outfit interim products. However, these can be temporary in the first instance. The location of temporary process lanes must be carefully considered so as not to affect material flow or to hinder the operation of other process lanes. The application of multi-skilled teams should be extended to these work areas in order to build a solid understanding of the operations.

As with the short-term performance improvements it will not be possible to implement all the ideal sizes and configurations of interim products, due mainly to the facility constraints, process limitations and the use of temporary process lanes. However, the mid-term developments will build on the short-term providing clear requirements for the specification of the long-term developments.

4.3 Long-term improvements

The long-term developments will realize the aim of achieving a world-class performance level and the development of fully integrated facilities and computerized support systems. All long-term developments must be an integral part of an overall corporate plan for the company. This must consider maximizing the use of resources and facilities while retaining the flexibility to compete in an ever-changing world shipbuilding market. Although categorized as long term, the far-reaching impact of a fundamental change in production technology needs to be addresses now if a structured development program with progressive performance improvements is to be successful.

Long-term developments would include a long-range facility plan addressing the implications of product oriented operations on the layout and operation of both steel and outfit facilities, the

development of integrated systems technology and a change in the overall organization structure and manning levels. To achieve the long term goals it is important to introduce a central 'management of change organization' to ensure that all development projects:

- lead towards a common goal,
- consider the broader, cross-functional implications,
- do not duplicate effort, and
- do not develop alternative or conflicting strategies and approaches.

Finally, there must be ongoing development of the various major elements highlighted in this document. It must be remembered that whenever, one part of the shipbuilding equation changes then the rest must change to balance the overall process.

NATIONAL STEEL AND SHIPBUILDING COMPANY
A GENERAL DYNAMICS COMPANY

NSRP PROJECT 8-98-2

Process Modeling to Improve Productivity of On-Board and On-Block Outfitting

Task 5 Deliverable

Define Generic Outfit Process Model

FIRST MARINE INTERNATIONAL LIMITED

OCTOBER 1999

Define Generic Outfit Process Model

CONTENTS **Page**

1. INTRODUCTION

In recent years NASSCO has made considerable progress in improving their performance in ship outfitting. This improvement is leading towards achieving a level of performance, which will be competitive in international commercial shipbuilding. The implementation of on-block and on-unit outfitting techniques, together with the development of workstation-style production information and the introduction of multi-skilled work teams has significantly reduced the outfit production man-hours and cycle time. This improvement has been achieved through a wide variety of highly focused production oriented projects. In support of this project, NASSCO is building on these achievements to create a firm foundation of performance necessary to achieve international competitiveness.

A recent project, funded under the Maritech program, developed an overall methodology for a product-oriented approach to outfit design and production based on a 'ship factory' concept. This has provided the necessary structure and cohesion by which future projects can be organized and managed for maximum benefit. The company realizes that they still need to further improve performance if they are to achieve competitiveness in the international commercial shipbuilding market.

This document forms part of the NSRP Project 8-98-2, Process Modeling to Improve Productivity of On-Board and On-Block Outfitting. The primary objective of the project is to establish a world-class methodology for the definition of outfit interim products, which can be competitively assembled and installed on a vessel in a multi-trade work environment. The development of a hierarchy of outfit interim products, which can be integrated with the steel structure at the optimum time in the assembly process, will significantly improve the performance of on-block and on- board vessel outfitting.

The following sections define the generic outfit process model, outfit assembly and installation production process activities required to implement a world-class, product-oriented, ship factory. The following deliverables should be read in conjunction with this document:

Task 2 Deliverable – NASSCO Current Outfit Production Process Activities,

Task 3 Deliverable – World-Class Outfit Production Process Activities, and

Task 4 Deliverable – Perform Comparative Analysis Between NASSCO Current and World-Class Outfit Production Process Activities.

The above documents are the basis for the development of the generic outfit process model and should be read in conjunction with this document. The elements selected for discussion are considered to be those which are fundamental to the successful implementation of a product-oriented approach to outfit design and construction. They include:

the definition of outfit interim products and a hierarchical assembly structure for integrated production processes,
the identification of the outfit on-block and on-board production processes including vessel hand-over,
the identification of necessary production support information for all stages of the process, and
the structure of the production support functions necessary to ensure successful implementation of a ship factory concept.

The objective of this document is to describe a world class product-oriented, workstation philosophy for outfit production activities. Also, a means for developing a structured set of design and engineering rules and decision making criteria, which when applied during the pre-production process, provides a consistent and logical method for the definition of outfit interim products. The approach involves defining a hierarchical interim product structure for the assembly and installation of outfit elements. From this, process lane and workstation operation models are generated to illustrate the methodology. Although not strictly within the terms of reference, the document refers to the development of a product oriented design and engineering process as a major factor in the development and implementation of the interim product structure.

This outfit production model is developed as part of this NSRP project and has drawn on previous MARITECH Ship Factory Transformation Projects, which focused on the development of integrated technology. The principal focus is on the previously identified range of outfit interim products and the production work centers and work stages of the build cycle of a ship.

This document describes an analytical approach to designing and establishing outfit assembly workstations. It describes:

- The effect of outfit production workstations on product design.

- The types of work centers within the shipyard.

- The method to determining and quantifying interim products.

- The method for calculating product area requirements.

2. PRODUCTION OF OUTFIT PRODUCTS

The philosophy described in Tasks 3 and 4 is to generate the designs of ships from a range of interim products that the shipbuilder, including sub contractors, can build economically. These interim products are developed in the 'shipbuilding strategy' product model and are used by design and engineering in each 'ship definition' product model. This approach has major benefits for the whole shipbuilding process as the ship design is intrinsically 'designed for production'. The design and engineering process benefits by using these 'pre-defined' products in both design lead time and manhour expenditure, thus, saving technical resources.

The range of outfit products, previous identified under the title "typical outfit part families" and "catalog of typical interim products", showed that outfit has a far wider range of well-defined part product types than that for steel structure. However, for the assembly stage, the situation is reversed with steel having a well-defined hierarchical product structure. This highlighted the need to identify a similar hierarchical range of outfit assembly products. Additionally, outfit assembly extends over all the shipbuilding stages, unlike structural interim products, which complete at the erection join-up stages. Figure 1 shows the outfitting work centers for a typical shipyard. The outfitting work centers will normally include the following workstations and work stages:

- Shop based outfit part manufacturing work centers, including the handling of raw material, plus, bought-in 'finished' items.
- Shop based outfit assembly work centers, including minor, sub, unit, block and grand-block assembly workstations for steel and outfit products.
- Ship based outfit assembly work centers, including the erection joint stages and onboard zone completions.
- Ship based outfit system testing, trials, completion and handover work.

Main Process Flow through Shipyard Work Centers

Each grouping of workstations in the main work centers require a different approach when applying production methods, information packages, supply of material and management control.

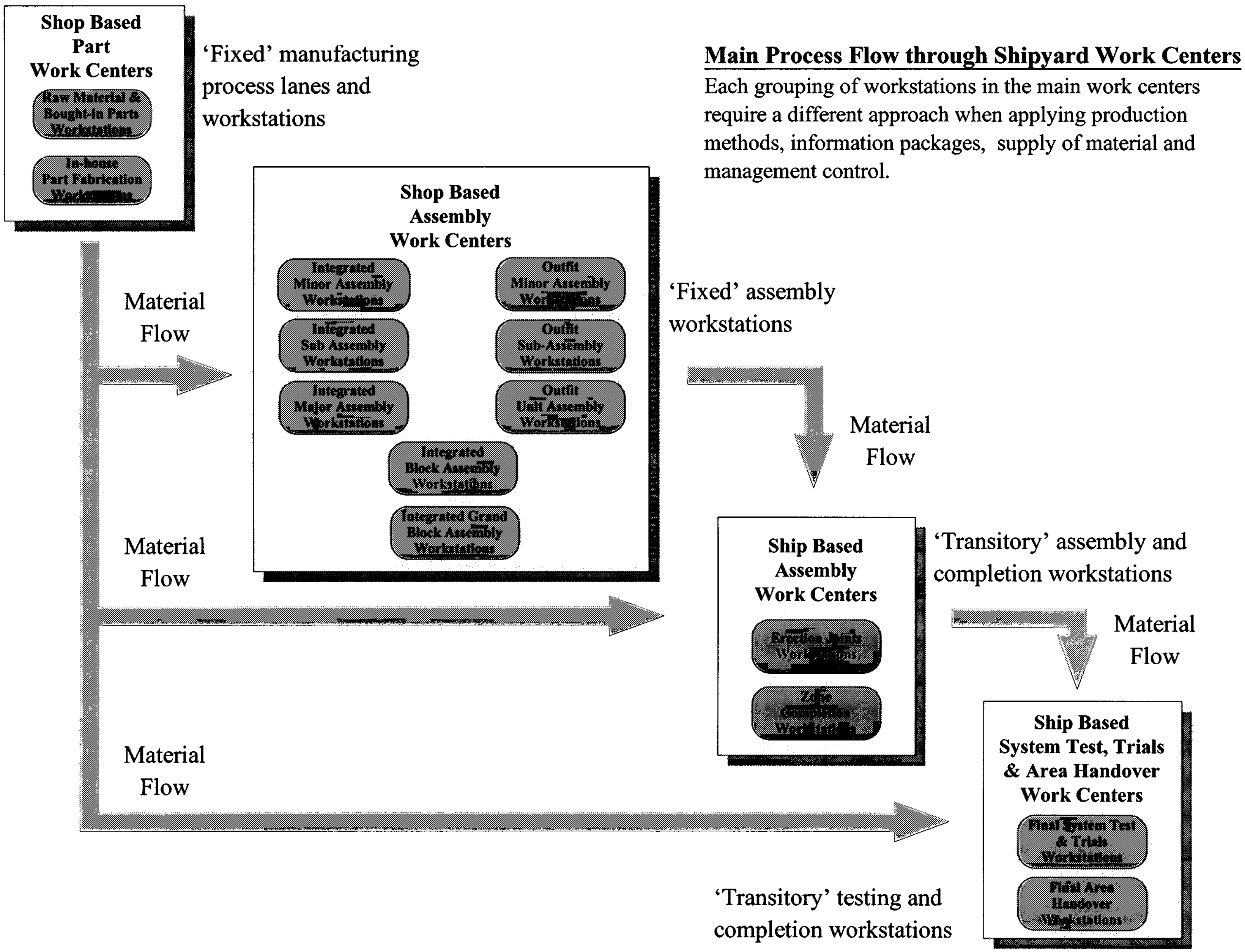


Figure 1

The overall process flow through the principal production work centers

3. STAGES OF OUTFIT PRODUCTION

The stages of outfit production cover a wide range of work from shop based manufacturing of parts through various shop based assembly work centers to ship based onboard zone completions including system testing, trials and handover work. Figure 2 illustrate the range of outfit work centers. Each work center or work stage will have requirements that affect the design of the outfit interim products and process. To design a range of 'economical' outfit interim products, it is essential to know the capabilities and limitations of these production facilities and processes. In this regard, facilities of sub-contractors should also be regarded as part of the shipyards own work centers.

The 'efficient' design of outfit products depends heavily on the processes and capabilities of the work centers where they are to be manufactured or assembled. Care is needed when developing the outfit products not to impose limiting production constraints within individual work areas. In this regard, limiting the design of interim products to a particular manufacturing process may inadvertently sub-optimize the product design required for later assembly stages where the size limitations may be imposed by a later assembly process. This may, in the short term, sub-optimize the use of existing manufacturing processes and require development of the production facilities to restore balance to the production process. However, it is the purpose of the shipbuilding strategy research and development process to ensure that products and processes are well tested prior to release to the ship definition process.

4. OUTFIT PRODUCTION WORK CENTERS

The design of each product type depends heavily on the capabilities and limitations imposed by the production processes and workstations. These 'facility' attributes form a major part of the data that is attached to the interim products. They allow the automatic association of the products to the relevant work centers, process lanes and workstations. The attributes range from high level, ship-shipyard attributes, required at the earliest concept design stage, down to the product-workstation level for actually producing the interim products.

Unlike structural products, outfit products cover a wider range of product families. The lowest level of interim products tends to be well defined and can easily be associated with their manufacturing processes and workstations. Conversely, the change to a more integrated approach to outfitting has considerably

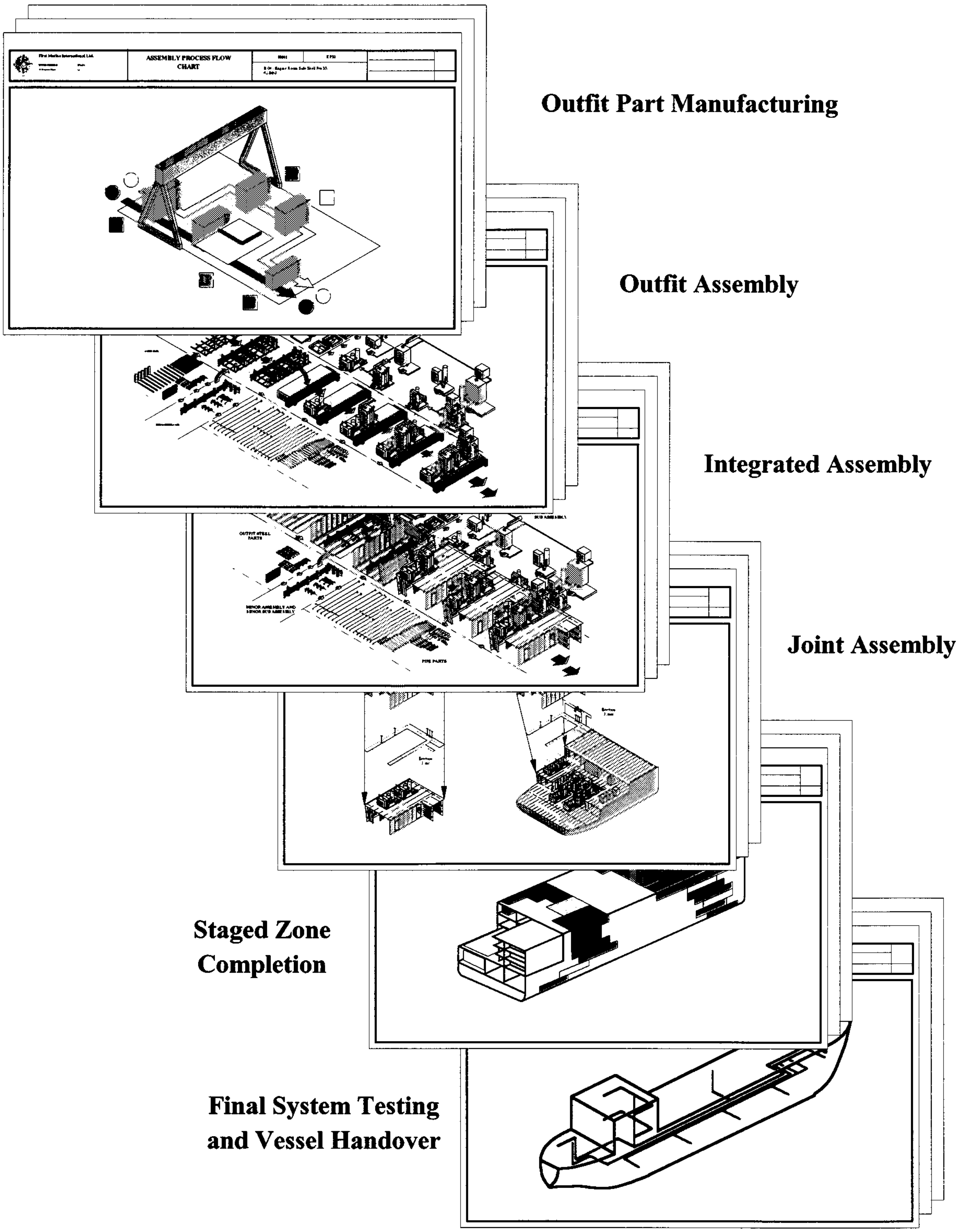


Figure 2
Stages of Outfit Production

altered the outfit assembly work stages and assembly workstations. In this regard, it is important to define the outfit assembly stages to match the changing shipbuilding methodology.

The following sub-sections describe the typical production stages and the processes that need to be considered in the development of outfit interim products and in matching them to the facility attributes.

4.1 Outfit manufacturing work centers

Outfit parts are used throughout the assembly process. Although many are bought-in items, there can be a large number of family types fabricated in-house such as metal outfit items, ventilation products and pipe spools. These in-house parts in addition to assembly attributes need information that directs them to the relevant outfit fabrication process. In some cases, there are alternative production processes for manufacturing or assembling the products. The example in figure 3 shows a 90-degree pipe and its alternative manufacturing processes.

In this example, the design requirements fix the overall size, however, the production process allows alternative process lanes to be used for fabricating the final product. In the traditional approach the engineer would have had to know in which lane the product would built or would have had to attach extra information to the sketch to cover all manufacturing eventualities. Whereas, in an integrated technology system, the system itself has the data and can be interactively linked to the workstation scheduling system. Thus, factors such as machine utilization can directly influence where to send the product for manufacture and the appropriate information will be selected automatically.

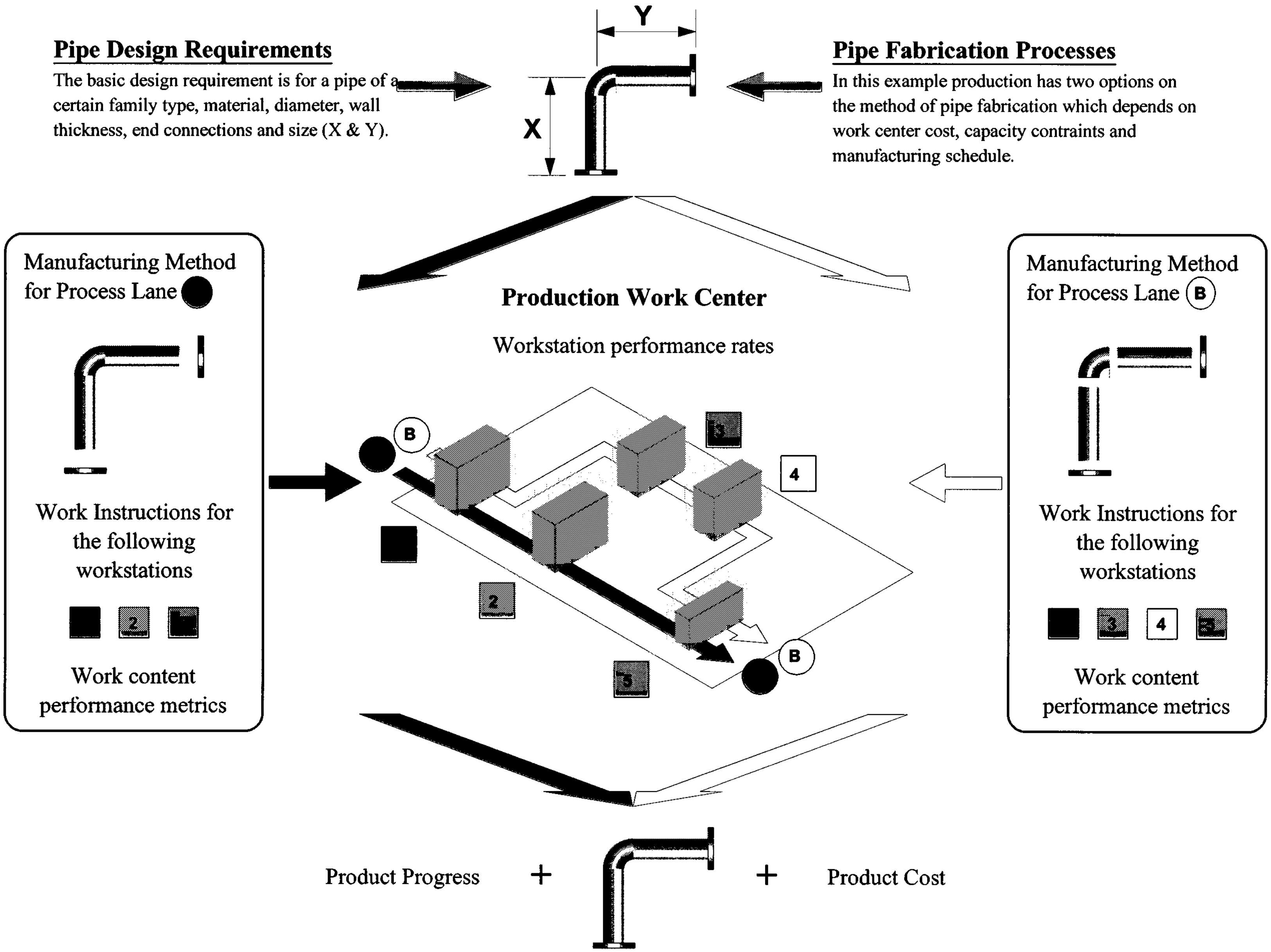


Figure 3
Alternative manufacturing processes affect the content of work instructions for the manufacturing work center

4.2 Outfit assembly work centers

In creating a factory approach to the process of assembling outfit items, there is a major change of emphasis from the traditional methods of advanced outfitting of blocks, to an integrated assembly methodology. There is a need to define and develop suitable outfit-oriented assembly work centers and processes lanes in order to maximize the efficiency of the assembly process. The design of the outfit process lanes is similar to that of structural product types and is based on the requirements for a hierarchical range of outfit assembly product types as described in the methodology for creating outfit products. The examples in figures 4 and 5 show the assembly of similar outfit minor and sub-assembly products into outfit units and into an integrated steel and outfit block. These examples demonstrate that the development of 'outfit' assembly process lanes can be purely outfit oriented, or integrated into a 'steel and outfit' block assembly facility. The methodology for sizing such a work center is described in section 6.

4.3 Joint assembly work center / work stage

When any integrated steel and outfit block or outfit unit is completed, the next assembly stage is a join-up process. This is more transitory in nature as it is done in many locations. Figure 6, shows examples of this join-up process for the assembly of a block to a grand block and direct to its shipboard location. In these examples, the labor and production services move to the work site rather than products flowing past a 'fixed' workstation location. The joint product itself is keyed on the erection process and is an easily identifiable product, with work associated with the structural connections and outfit products across the erection joints completing by stages.

The join-up 'assembly' stage is the transition from shop based build to ship based completion. In order to reduce vessel cycle time, this work stage is a starting point to implementing a 'rolling wave' approach to the completion of onboard zones.

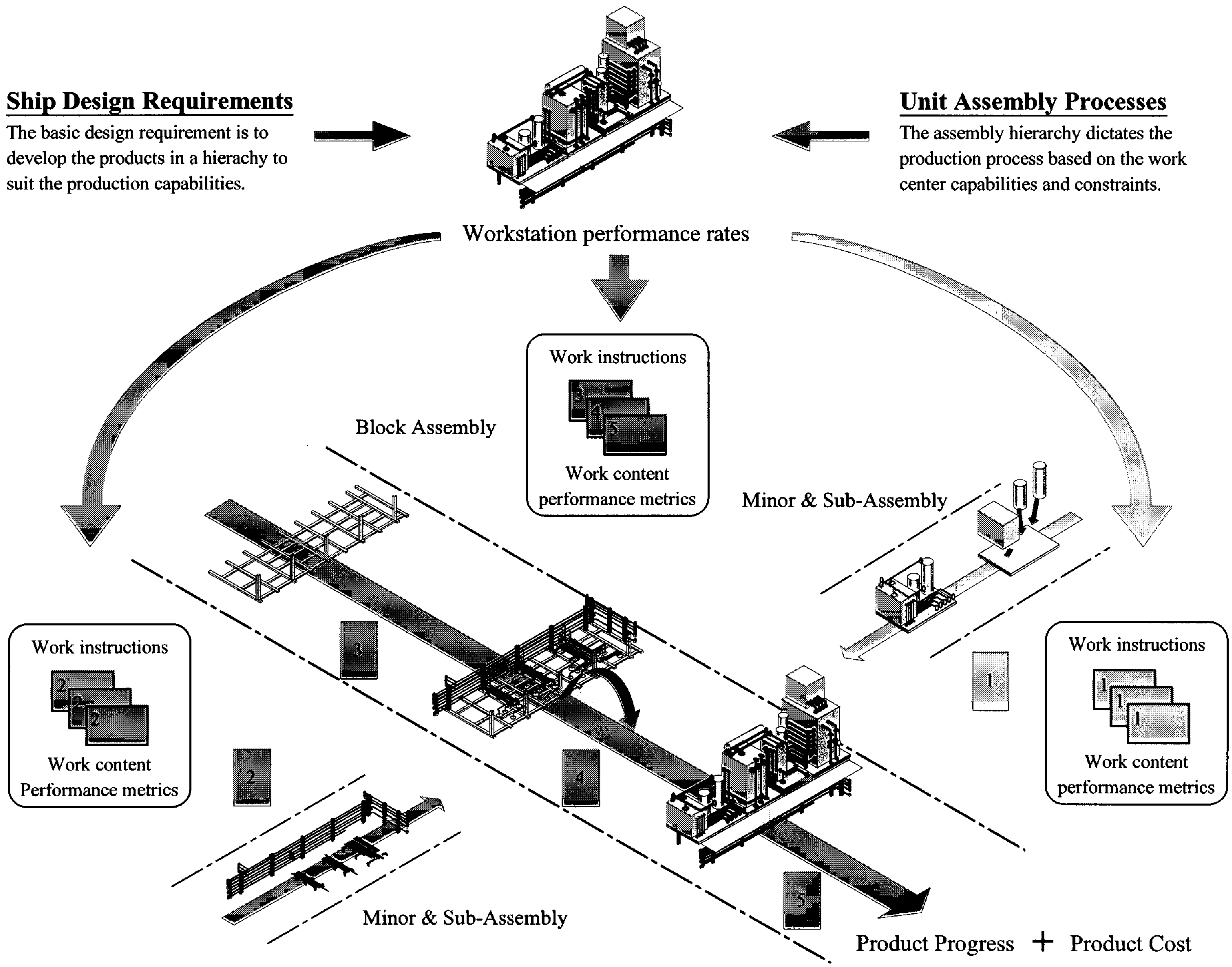


Figure 4
Typical Outfit Process Flow for Minor, Sub and Unit Assembly Work Centers

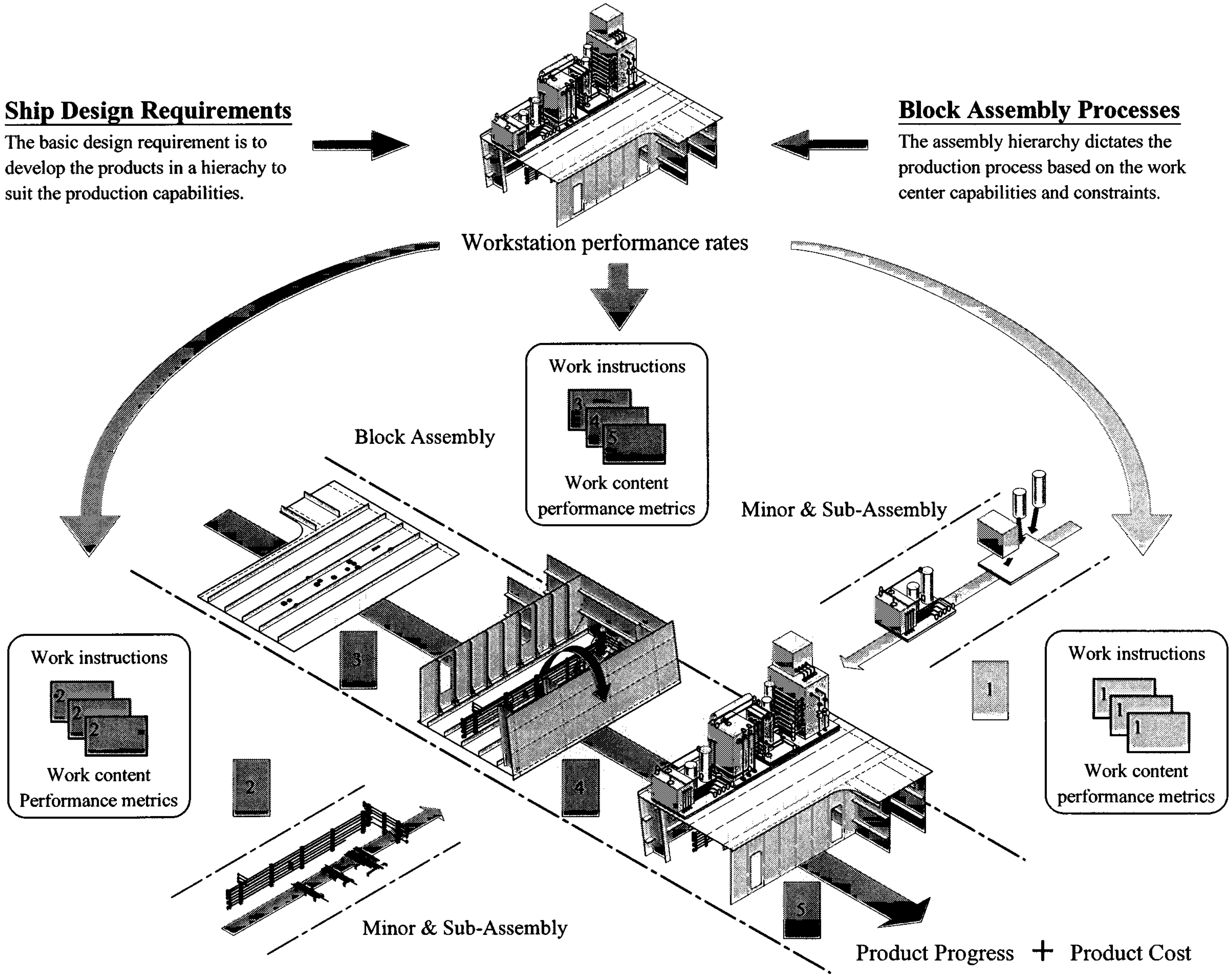


Figure 5

Typical Process Flow for Minor, Sub and Block Assembly Work Centers

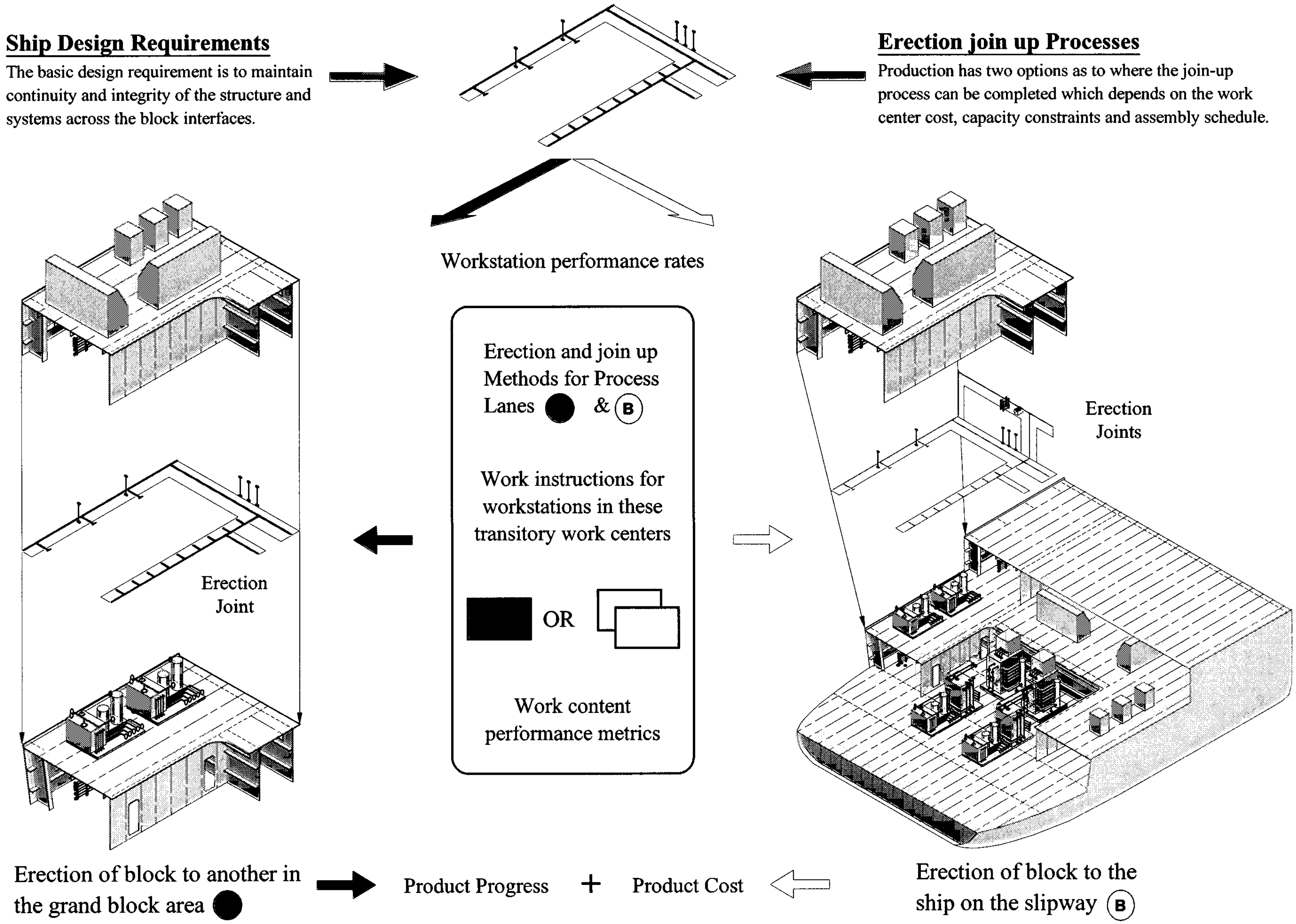


Figure 6

Typical process flow for the transitory locations of the block erection and join up work centers

4.4 Zone completion work stage

Following the erection join-up stage, the 'final' stage of assembly of outfit products can be undertaken. This work includes the fitting of products that cannot be installed in short sections such as main cabling, and the installation of the more fragile products into the onboard zones and final painting of the ship areas.

Applying the integrated approach to outfit installation, the amount of work remaining at this stage should be small. However, this will be dictated by limits imposed by the erection cranage on the size of blocks and the ability to complete the outfitting of any fully enclosed zones.

4.5 Testing and completion work stage

The final stage of work is the commissioning and vessel handover process. This normally includes testing of the various ships systems, which traditionally, have been completed at the end of the vessel construction process. The integrated build approach demands that testing is phased across the whole build process. In some functional areas, the advanced build of products and their systems ensures that it is possible to complete and test them prior to launch, although it is unlikely that all testing after launch will be eliminated. There is also at this stage, the general vessel and handover work that must be completed. On a complex vessel, this can be a major package of work, which is often not well defined.

5. ATTRIBUTES OF THE PRODUCTION FACILITIES

A key to the operation of integrated outfit production is identifying the requirements, capabilities and limitations of the production facilities. These facility attributes are associated with each product type in the shipbuilding strategy database and are accessed through the links in the ship definition product model to the various shipbuilding processes such as planning and scheduling. This ensures that these facilities requirements are automatically incorporated into the definition of every ship product model.

The hierarchical development of the outfit interim products structure allows the development of multiple levels of facility information. Thus, as the ship definition develops, the facility requirements can be examined and refined. For example, the work center resource loading and overall planning can be determined by utilizing general work center attributes. Similarly, at a lower level of facility attribute, the products manufacturing attributes are used to match the products to the correct production processes. In

the example of a pipe spool, the products would link through such attributes as:

- The pipe product family type. This identifies where the types of product can be made, at which workstation and if the product can use alternative process lanes.
- The work content for each workstation operation. This is linked to the work rates for each operation and can be used in determine workstation loading and cycle time.

The combination of these attributes allows the scheduling system to determine which process lane is best suited to make a particular product and, in an interactive system, workstation loading can be achieved in real time. Once the process lane is determined, the system can select the appropriate manufacturing attribute.

These include the physical parameters such as pipe length, pipe diameter, wall thickness, materials and end connection types needed for operating the individual workstations. This is matched to the corresponding physical parameters of the individual workstations such as bend radius, bend length limitation and pipe mandrill diameter, which limit the operations of the workstation.

The process of linking products to facilities is similar across all stages of production but will require the appropriate facility attribute to be defined for all levels of the production facilities. There are additional attributes which, are either design function related or performance measurement related.

6. DESIGNING OUTFIT WORK CENTERS

The design of an outfit assembly factory requires the identification of an outfit interim product hierarchy and the quantification of each product type. This process was described in previous Tasks, and is used as the starting point for designing the outfit assembly workstations. The process of designing production facilities uses some of the product attributes such as type, floor area requirement and cycle time to determine the size of production work center. The principal outputs of this process are described in the following sub-section, and may be grouped under the term ‘process analysis’.

6.1 Process engineering formats

A typical format, seen in figure 7, shows process engineering for the assembly of an integrated steel and outfit block as a central flow lane with side lanes for the various lower levels of steel and outfit interim products. It is a pictorial format, which is useful for discussing the process engineering with design, engineering, planning and production.

Process engineering pictures can be prepared for each outfit unit, integrated steel and outfit block, outfit unit, block erection joint and zone completion stage. These can then be agreed with the relevant pre-production and production departments.

6.2 Process flow chart

The process flow chart, figure 8, shows the hierarchical assembly of an integrated steel and outfit block and quantifies the steel and outfit interim products by type and stage. There are many interpretations of what constitutes steel and outfit interim product types and what constitutes a production stage. The normal method when developing workstations is a division of production stage, product type and product family.

The following points describe the format and content of the flow chart:

- Production stage column: includes parts, minor assembly, sub-assembly and block assembly. These extend to include the erection joint, zone completion and the final system testing and commissioning stages, since each of these ship based completion stages also use the same lower level interim products.

- Product type column: includes steel and outfit parts. The parts extend to cover all the steel and outfit product types in these 'part' stages. Steel and outfit minor assemblies in the minor assembly stage. Steel and outfit sub-assemblies and major sub-assemblies in the steel and outfit sub-assembly stage. Unit, block and grand block in the steel and outfit block assembly stage.

When preparing the interim product analysis for the shipyard's production program, the interim products are defined only to the level of product type. Later, after developing the interim product summary, the product types are grouped into families. It is the product families, which are used in the definition of the workstations.

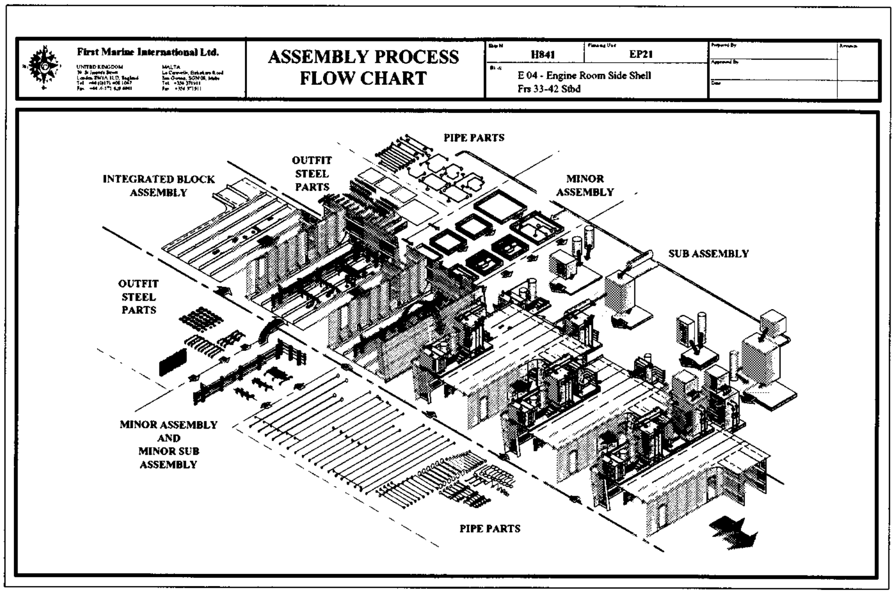


Figure 7

A Sample of Integrated Steel and Outfit Process Engineering

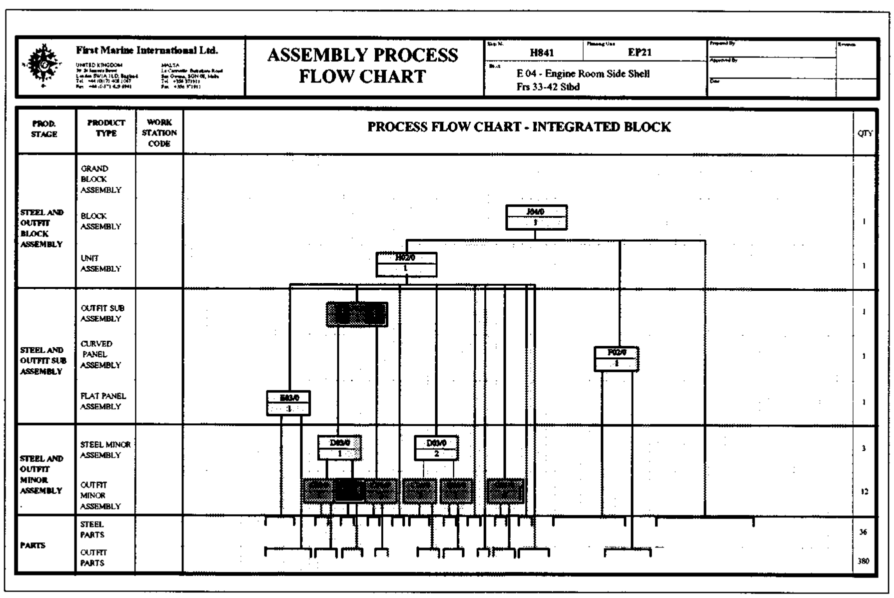


Figure 8

Typical Integrated Steel and Outfit Process Flow Chart

6.3 Summarizing and rationalizing the outfit interim products

When the process engineering and process flow charts have been completed for all the units, blocks, erection joints and zones of all the vessels in the production program. The numbers of interim products are summarized on an interim product summary sheet, similar to that shown in figure 9.

The summary sheet quantifies the outfit interim products by assembly stage and product type for all vessels. This summary identifies the products by their primary zone. It can also be used in assessing the requirements of the on-flow and off-flow production areas. From this summary, the interim products for each product type are reassessed. The objective is to examine the processes necessary to produce each interim product and to group products requiring similar processes.

It is unlikely that all interim products can be made identical in terms of production process. However, a rationalization exercise prior to the detailed definition of a vessel will ensure that as few different processes as possible will be required.

When this process is complete, these outfit interim product types are further defined into families according to their production processes, see figure 10.

6.4 Presenting the interim product analysis

After the outfit interim products have been rationalized by process into product families the final stage of the product analysis is to develop the basic parameters for designing the outfit assembly workstations.

The basic parameters used in designing outfit assembly workstations are floor area, weight and work content. The workstations are progressively designed beginning with the definition and layout area for each production stage, followed by the layout of the product areas within each stage and finally the workstation for the different product families, see figure 11.

On the left of the sheet is a summary of the information from the interim product summary including the production stage, product type and product family, together with the quantities of interim products in each. To the right is a summary of the average floor area, weight and number of parts. The averages are developed first within the product families, then summarized by product type and finally by production stage.

First Marine International Ltd.

INTERIM PRODUCT SUMMARY

15,000 Dwt Multi Purpose Vessel
7,700 Dwt Products Carrier
Car / Passenger Ferry

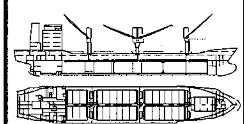
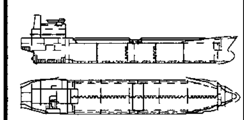
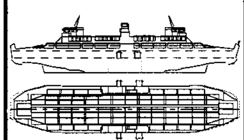
PRODUCT RANGE	Stage	Outfit Part Preparation	Outfit Minor Assembly		Sub Assembly			Block Assembly		
	Product Type									
	Product Family									
15,000 Dwt Multi Purpose Vessel 	Accommodation Zone		56	44	12		14	12	8	2
	Engine Room Zone		139	125	21	10	44	8	16	1
	Cargo Hold Zone		436	285	64	10	88	74	39	
	Forward End Zone		34	23	4	2	10	8	2	1
	After End Zone		45	31	6	2	8	5	2	1
	SHIP TOTALS		**710**	**508**	**107**	**24**	**164**	**107**	**67**	**5**
7,700 Dwt Products Tanker 	Accommodation Zone		43	34	9		11	9	6	2
	Engine Room Zone		107	96	16	8	34	6	12	1
	Cargo Hold Zone		335	219	49	8	68	57	30	
	Forward End Zone		26	18	3	2	8	6	2	1
	After End Zone		35	24	5	2	6	4	2	1
	SHIP TOTALS		**546**	**391**	**82**	**20**	**127**	**82**	**52**	**5**
Car / Passenger Ferry 	Accommodation Zone		14	12			4	3	2	
	Engine Room Zone		35	32	4	4	12	2	4	
	Cargo Hold Zone		57	42	6	4	14	12	6	
	Forward End Zone		12	9	1		5	3	1	
	After End Zone		12	9	1		5	3	1	
	SHIP TOTALS		**130**	**104**	**12**	**8**	**40**	**23**	**14**	
PRODUCT RANGE TOTALS			**1386**	**1003**	**201**	**52**	**331**	**212**	**133**	**10**

Figure 9
Typical Integrated Steel and Outfit Product Summary

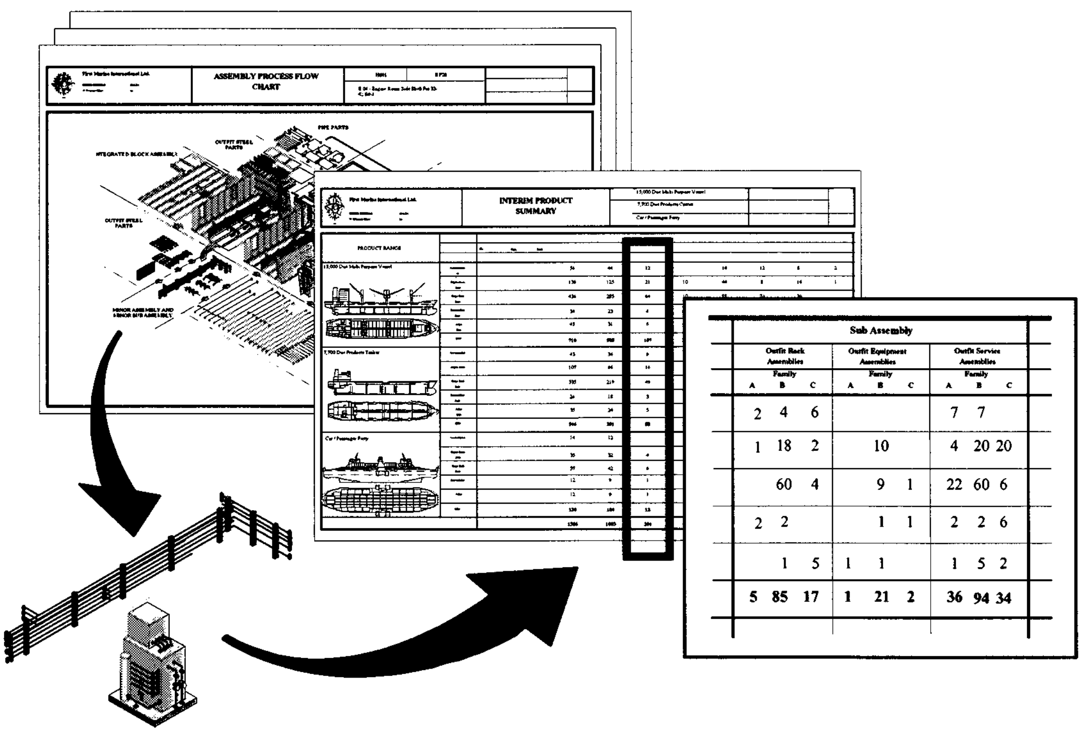


Figure 10
Rationalization of Integrated Steel and Outfit Products

The product analysis is a time consuming process. However it is crucial to the design and effective operation of workstations. Time spent in production engineering and product analysis is essential in order to maximize efficiency and effectiveness of the workstations.

6.5 Sizing of outfit work centers and workstations

The first step is to determine the overall area requirement. One metric for determining the level of facility utilization is throughput per square foot of floor area per annum using the interim product analysis summary, the areas are calculated using the formula:

$$\text{Area} = \frac{\text{Total area of the interim products x access area factor x Estimated floor time for interim products}}{\text{Cycle time for the vessels}}$$

- The area of the interim products is taken from the interim product analysis
- The access area factor is the allowance for storage areas, accessways and input and output areas
- The floor time for each type of interim products is defined in terms of days
- The vessel cycle time is the target number of working days for the construction of the vessel. With more than one vessel in a product range then the mean vessel cycle time may be used.

Once the area calculations are complete, work can start on the layout and design of the workstations. The first step is to prepare a block layout of the various product areas as shown in figure 11. Each area is examined in detail and the workstations for each product family developed.

NATIONAL STEEL AND SHIPBUILDING COMPANY
A GENERAL DYNAMICS COMPANY

NSRP PROJECT 8-98-2

(NATIONAL SHIPBUILDING RESEARCH PROGRAM)

Process Modeling to Improve Productivity of On-Board and On-Block Outfitting

Task 6 Deliverable

Develop Shipyard Specific Outfit Process Model

FIRST MARINE INTERNATIONAL LIMITED

MAY 2000

Develop Shipyard Specific Outfit Process Model

CONTENTS **Page**

1. INTRODUCTION

In recent years NASSCO has made considerable progress in improving their performance in ship outfitting. This improvement is leading towards achieving a level of performance, which will be competitive in international commercial shipbuilding. The implementation of on-block and on-unit outfitting techniques, together with the development of workstation-style production information and the introduction of multi-skilled work teams has significantly reduced the outfit production man-hours and cycle time. This improvement has been achieved through a wide variety of highly focused production oriented projects. In support of this project, NASSCO is building on these achievements to create a firm foundation of performance necessary to achieve international competitiveness.

This document forms part of the NSRP Project 8-98-2, Process Modeling to Improve Productivity of On-Board and On-Block Outfitting. The primary objective of the project is to establish a world-class methodology for the definition of outfit interim products. The development of a hierarchy of outfit interim products, which can be integrated with the steel structure at the optimum time in the assembly process, will significantly improve the performance of on-block and on- board vessel outfitting.

The following sections define the shipyard specific outfit process model that was developed to demonstrate the next step towards outfit assembly and installation production process activities required to implement a product-oriented, approach. The following deliverables should be read in conjunction with this document:

1) Task 2 Deliverable – NASSCO Current Outfit Production Process Activities,

2) Task 3 Deliverable – World-Class Outfit Production Process Activities, and

3) Task 4 Deliverable – Perform Comparative Analysis Between NASSCO Current and World-Class Outfit Production Process Activities, and

4) Task 5 Deliverable – Define Generic Outfit Process Model.

The above documents are the basis for the development of the shipyard specific outfit process model and should be read in conjunction with this document.

2. OBJECTIVE

The objective of this document is to describe the shipyard specific outfit process model that was utilized to demonstrate a product-oriented, workstation philosophy for outfit production activities. The approach involves defining a hierarchical interim product structure for the assembly and installation of outfit elements.

This shipyard specific outfit process model is developed as part of this NSRP project and has drawn on previous MARITECH Ship Factory Transformation Projects, which focused on the development of integrated technology. The principal focus is on the previously identified range of outfit interim products and the production work centers and work stages of the build cycle of a ship.

3. PILOT SELECTION

The original technical proposal stated *"When approved by the Steering Committee, and upon award of a new ship building program at NASSCO, Project Team members will initiate the implementation process."*

After the start of the project it was realized, due to market conditions, that the application of this improved outfit process model would not be possible on a new program given the project schedule. So the focus for implementation was shifted to the, SLNC, Sea Lift New Construction program that was currently underway. The SLNC program was already well along but the schedule still offered the opportunity for

implementation on the seventh ship of the class, the SLNC-7. Additionally, after the decision was made to implement on the SLNC-7 a contract was awarded to NASSCO for an eighth ship of the class which will allow for further refinement of the process model.

As was stated previously, during development of SLNC strategies concerted efforts were made to move towards an interim product approach. This was done effectively in some areas, especially in the area of machinery unitization, but the majority of the ship was still designed using a traditional outfitting approach. This traditional outfitting approach, or block and zone outfitting, created the need for a large number of outfitting parts to be brought to the workstations that consume them. In the case of the SLNC these are the On-Block and On-Board areas. Even in the areas that machinery unitization were apllied, the units were of such a large size and complex level that they still required large numbers of outfitting parts to be brought to On-Block areas were these products were built.

The decision was made to further build on the successes of the unitzation program and refine it by way of the application of the interim product approach along with specific method improvements that have been identified during the SLNC program. As part of this NSRP project, an area of the Sea Lift engine room, as shown in Figure 1, was selected for the pilot. The intent of the pilot was to demonstrate the fundamental philosophy of a product orientated outfit production process approach that has been discussed in previous documents. Furthermore, the objective of the pilot project, was to evaluate the design and production process approach within the current organization and to suggest any corrective measures or developments prior to full implementation of the interim product concept.

The pilot area selected was one of the intermediate levels of the engine room. Specifically, the 34'-7" flat, starboard side, aft. Within this area of the ship are systems

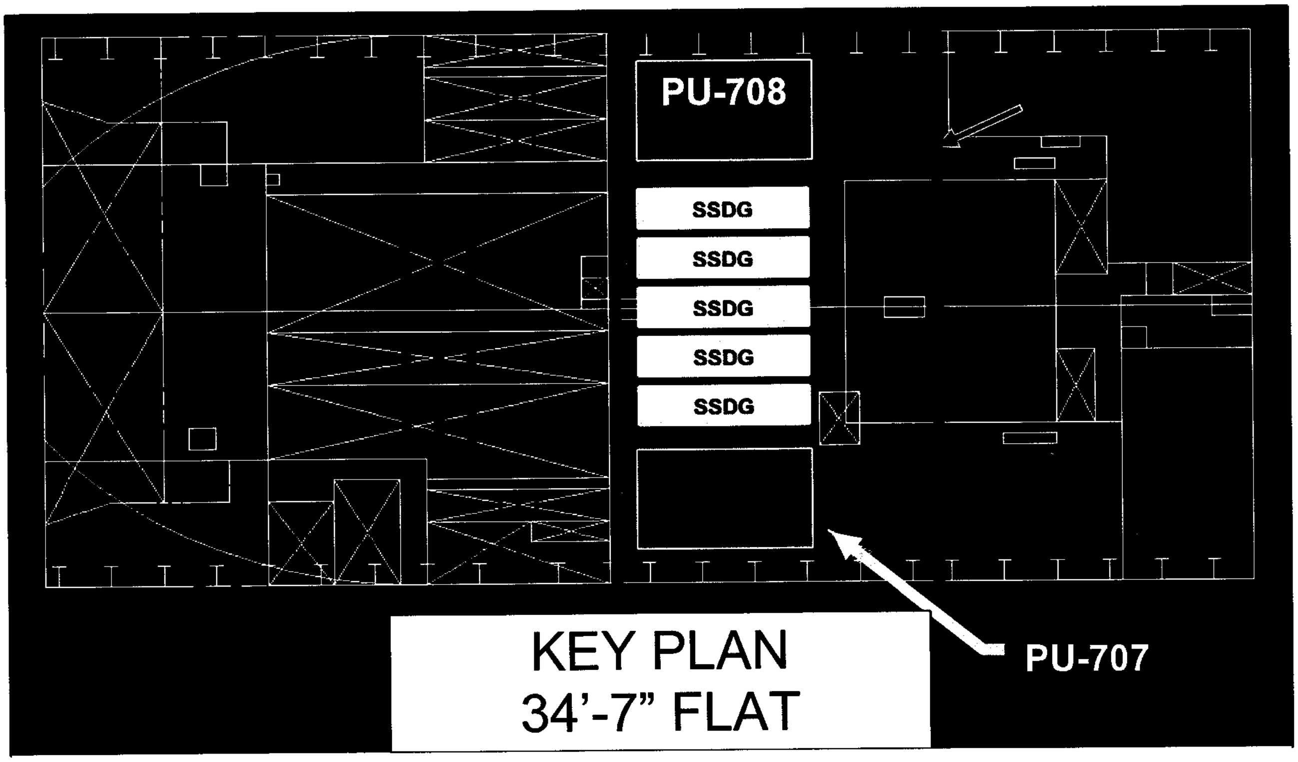


Figure 1 - SLNC Engine Room Arrangment

that support the Ships Service Diesel Generators along with other specific ships functional systems. The area is part of a major grand-block that includes the generator flat which spans from side shell to side shell at the 34'-7" flat. The pilot focused on a large outfitting block/machinery unit in this area along with its interfacing outfit and structure. The machinery unit was commonly known as Pipe Unit #707 (PU-707).

The outfitting unit as it currently exists for SLNC 1 through 6 consists of a foundation made up of angles, beams, and deck plates that support distributive systems, tanks, and equipment for the Starting, Control, and Ships Service Air systems; Lube Oil Transfer system; Stern Tube Lip Tank and Electrical Group Control Center, Load Centers, and Display Panel. Figures 2 and 3 show PU-707, for SLNC-6, during various stages of the outfitting fabrication process in the On-Block area.

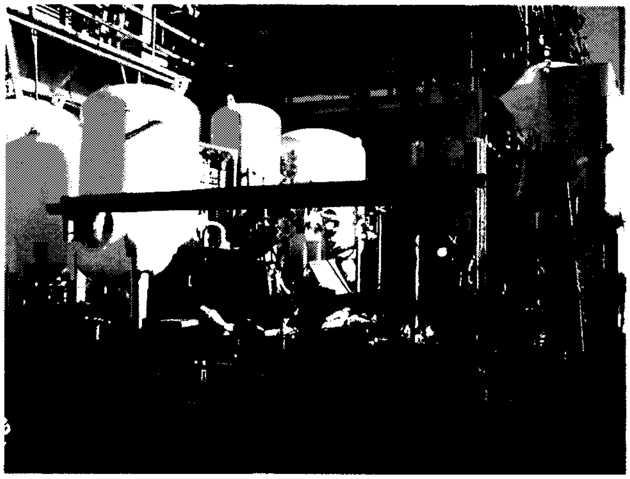


Figure 2 - Unit 707

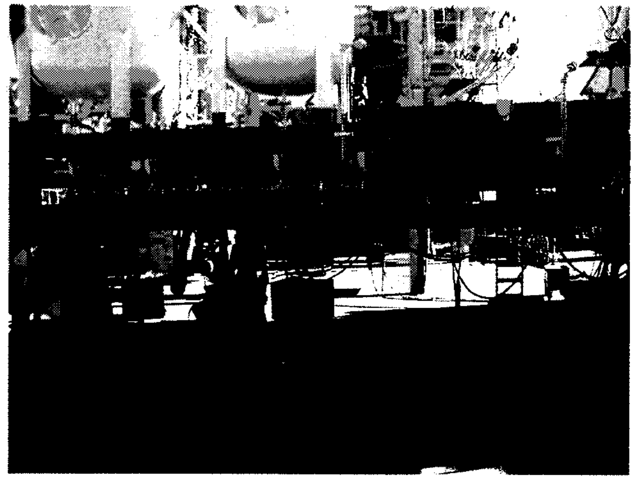


Figure 3 - Unit 707

4. DESIGN PROCESS

The traditional approach to unit design begins in the Machinery Arrangement process. At this stage, functionally related equipment, systems and tanks are located to reduce distributed system footage and maximize unitization potential. The goal is to identify the largest possible assembly of equipment and outfitting components that can be completed off the ship, assembled concurrently with the block and easily lifted without exceeding crane-lifting capacities. The final unit content and layout is confirmed by a series of studies, build strategy and preliminary system routing. Each unit is then assigned to a designer for detail development. The detail design process begins with the Metal Outfitting Designer creating the basic unit structure. He is then followed approximately two weeks later by the piping and electrical designers. Due to several factors including the abilities and expertise of each individual designer, the units on any given vessel are generally treated as unique. As a result of the inherent complexity of the equipment and structural arrangement, important features such as access and lifting requirements are added. At design completion the drawing and parts list is handed to a planner who assigns the material content to multiple construction pallets by trade and production budgets are assigned.

4.1 REVISED OUTFIT DESIGN PROCESS

Input to the design included the general structural configuration, systems diagrams arrangement drawing, purchase specs and composite drawings previously developed as part of construction program. The pilot project team were then to develop the product model design of the selected area of the vessel.

From the onset of the project it was realized that the interim product-orientated design function lacked formal documentation defining shipyard specific, interim product assembly methods. Input other than basic design information would have to be gained through regular meetings with members of the project team along with other shipyard departments to develop an appropriate product assembly and installation strategy. These meetings included all of the departments that where directly effected by the redesign.

The foundation vendor was also brought into the process early in order to incorporate their specific production processes into the design. Considerations for over the road transportation of the various structural components were included.

Support trades such as the rigging department were brought into the design process to eliminate work that is traditionally done late in the construction process. The rigging engineer provided input to the design by locating lifting points for safest transportation of the assembly and sub-assemblies. Pad eyes were included in the design at the specified locations. Outfitting interference was designed away from these locations as much as possible.

Recent developments in ship production technology are leading to the development of a fully integrated steel and outfit construction process. This means that steel and outfit interim products are combined at the optimum stage in the build process. It is possible to combine parts and assemblies of all types at various construction stages in a series of interim products that match the capabilities of the production processes.

Such a product-oriented philosophy also requires that the design and engineering process be similarly product-oriented in both organization and what they create. That is to say, a hierarchy of multi-system assemblies or interim products must be pre-defined and applied during the design and engineering process. These interim products being integrated at the optimum time in the assembly and construction cycle to minimize cost and cycle time.

Previous deliverables laid the groundwork in order to develop this approach; a generic interim product structure was first generated based upon the constraints of the facility and optimization of the production processes and is used to reflect the impact of an interim product structure throughout the design and engineering process.

The generic interim product structure is applied during the design of a new vessel. The use of pre-defined interim products may reduce the lead-time and man-hours traditionally associated with the development of a new ship design. Also, having a defined product structure enables the implications of a change in product, method or process to be fully analyzed prior to implementation on a live contract and reduces the extent of production unknowns, inherent in a traditional system oriented approach.

This approach ensures that the design of a specific vessel or interim product optimizes the utilization of facilities, processes and manpower as well as meeting the functional requirements of the owner and regulatory bodies. This approach was used in the development of the new design for Unit 707 and piloted the approach for the new, product-oriented processes.

5. REVISED PRODUCT MODEL

As was stated previously one of the first steps in establishing a product oriented approach is to develop an interim product structure. After several iterations a product hierarchy for PU-707 was adopted as is shown in Figure 4. This product structure was based on multiple factors such as interim product size, work content, defined production

processes and ship system functionality.

Because this unit would be installed on an existing ship design near contract completion there were some limitations to the extent the unit could be modified. One of the major constraints that had to be dealt with was the fact that the selected pipe unit would be installed on board a follow-on ship. This meant that the interfaces and spatial constraints were fixed. Physical location of each of the pieces of equipment, overall dimensions and interface connections could only be modified slightly from previous hulls.

The overall dimensions could not be increased. Pipe Connections to the supporting block could be modified only where absolutely necessary. The equipment had to remain, in more or less the same location. The drawing format had to remain

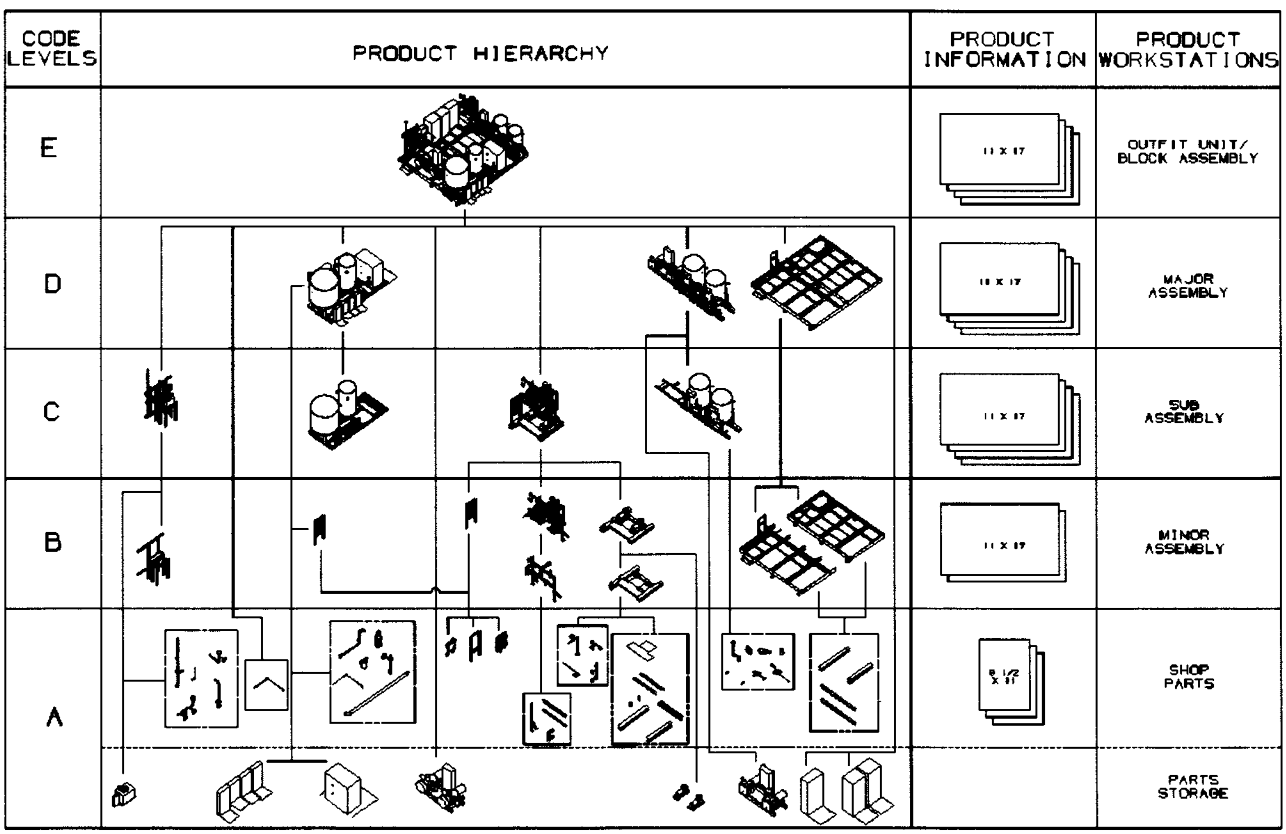


Figure 4 - Unit 707 product hierarchy

similar.

Some of the goals that were set as the original design was modified were as follows:

- Create lower tier assemblies wherever possible.
- Minimize the number of parts required
- All outfitting to be installed in exposed locations.
- Pipe spool adjustment will be at foundation or hanger in lieu of field welds.
- Eliminate the need for welding at the assembly stage.
- Rack pipe where possible.
- Install all outfitting in easily accessible locations.
- Provide hinged floor plate access and cable tray support to remotely located cable.

Maintaining these sorts of goals, along with the focus of reducing the amount of time and man-hours it would take to erect and install the material at the on-block and on-board locations led to the new model. In applying the adopted product hierarchy the new product model evolved into that which is shown in Figure 5 and 6. These figures show the redesigned PU-707 in its final assembled configuration along with an exploded view of the pipe unit and its assemblies at the higher levels. Each of these products also follow the interim product approach and can be further taken down to the next levels in the hierarchy. An example of this is shown in Figure 7 using the SSDG lube oil transfer sub assembly.

To support the interim product approach discussions were held with rigging to determine preferred lifting points. Permanently mounted pad eyes were installed as close to these ideal positions as possible. Modules were to be designed for the flexibility of being road transportable. Production was brought in early in the design to discuss build strategy and tailoring production information to suit each stage of construction. Vendors who would be constructing structural framework were also exposed to design and production information as early in the design as possible.

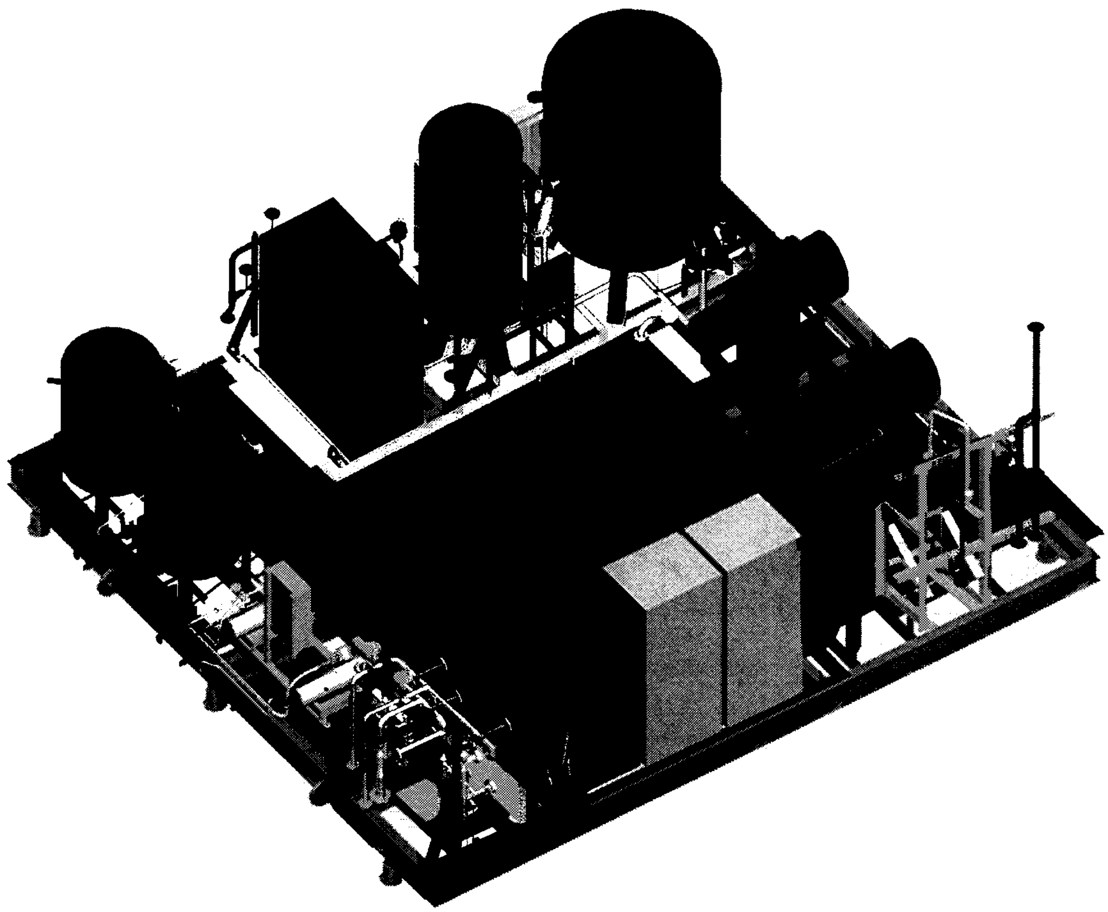


Figure 5 - Isometric view of redesigned PU-707

The revised product model optimized the number of assemblies that were created. This product structure allowed for a repeatability of assemblies. Flanged make-ups between assemblies, equipment, and unit interfaces were maximized. All local electrical cable trays, which were previously undocumented and installed on-board after erection, were moved from underneath the unit structure to the perimeter. This moved the work to a different stage of construction and an easier location for the trades' person to install the cabling. Safety was also improved by eliminating awkward maneuvers in tight spaces. The number of parts were reduced and make-ups designed to be flexible.

In order to ensure the successful application of this new process model a revised

production information format along with an implementation plan were developed. These will be discussed in the next deliverable.

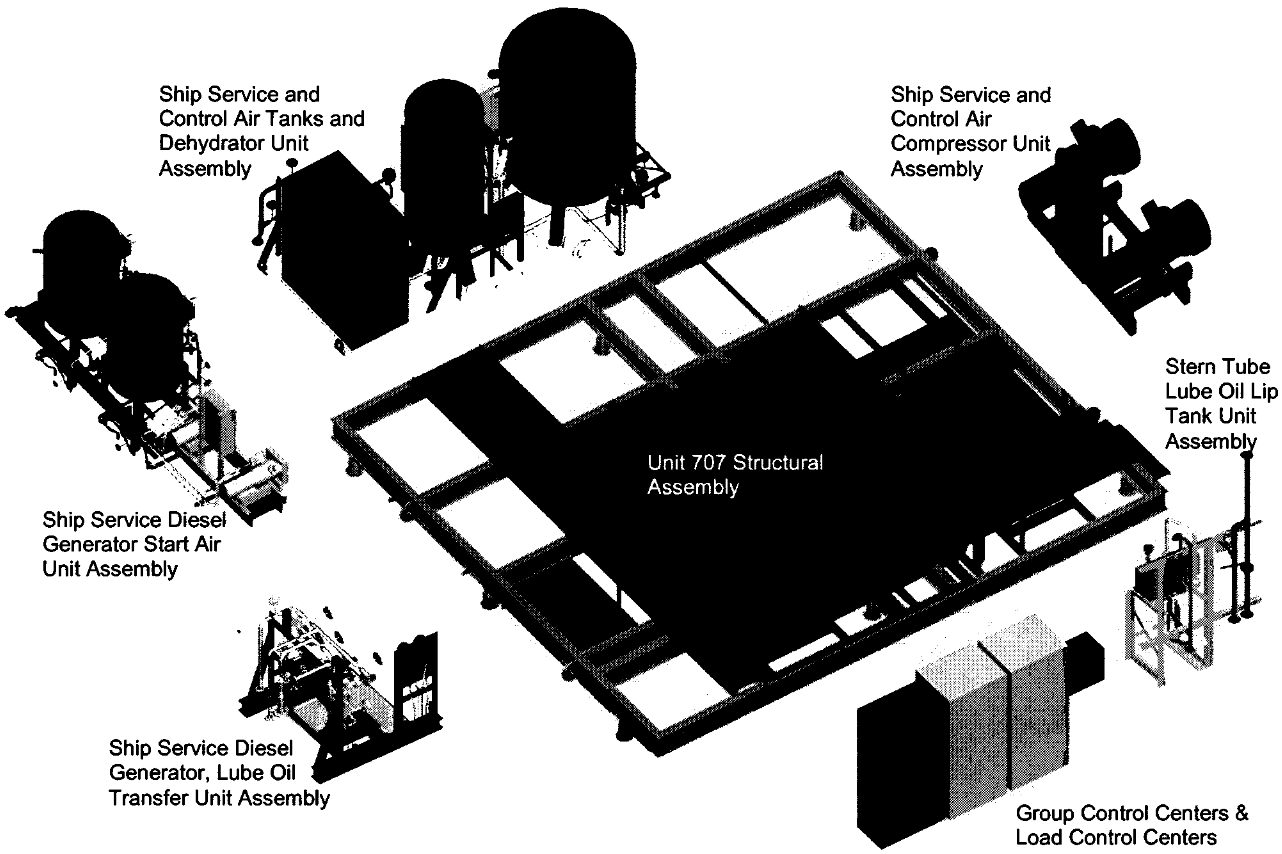


Figure 6 - Exploded view of PU-707

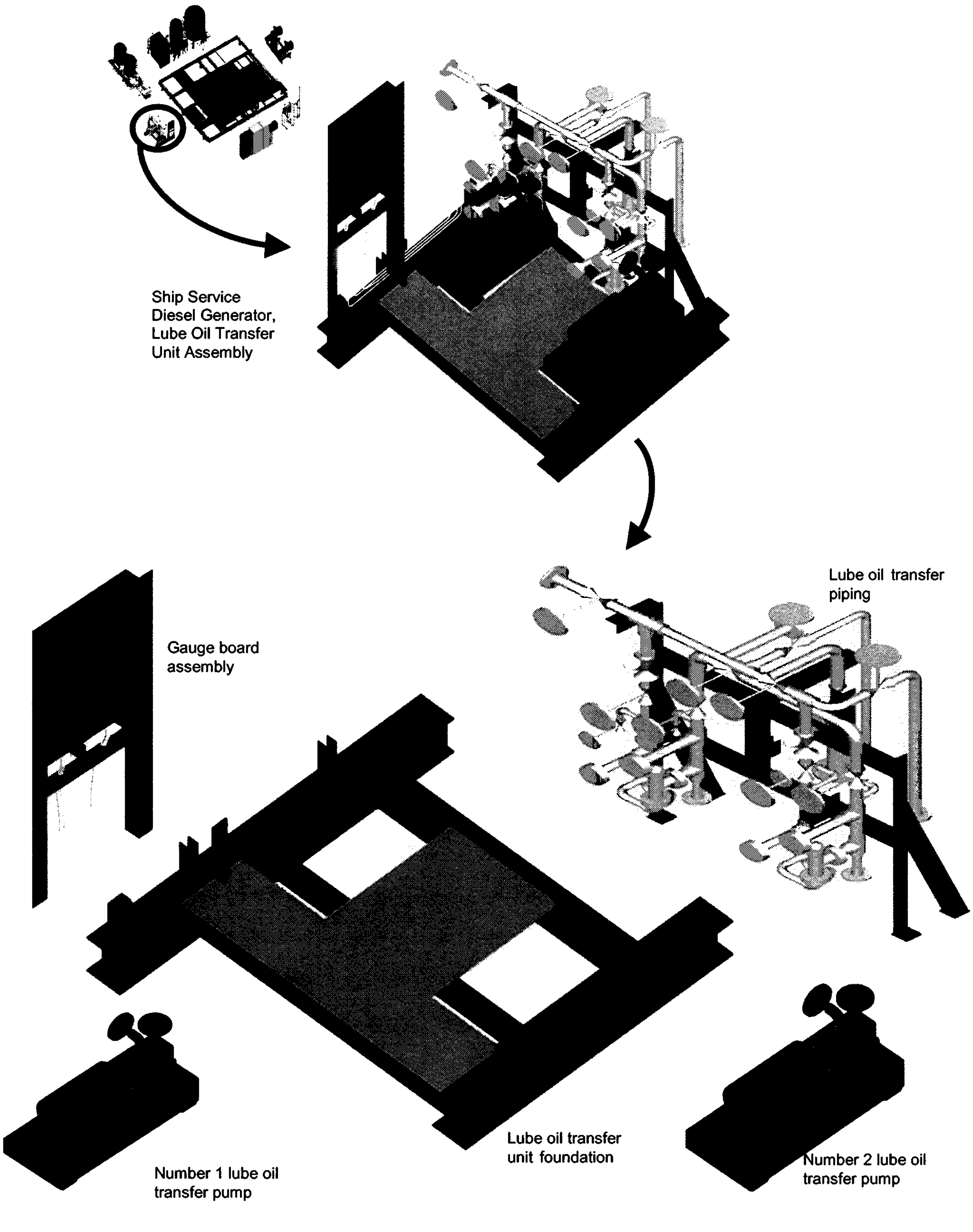


Figure 7 – SSDG Lube Oil Transfer Unit Assembly

NATIONAL STEEL AND SHIPBUILDING COMPANY
A GENERAL DYNAMICS COMPANY

NSRP PROJECT 8-98-2

Process Modeling to Improve Productivity of On-Board and On-Block Outfitting

Task 7 Deliverable

Implement Improved Outfit Process Model

FIRST MARINE INTERNATIONAL LIMITED

JUNE 2000

Implement Improved Outfit Process Model

CONTENTS **Page**

Appendix A – COMSC (Commander Military Sealift Command) Drawing Number 185-6979211; SU-707, START/SVCR/CONT AIR, 34'-7" FLAT, FR 112-116 S.

Appendix B – COMSC (Commander Military Sealift Command) Drawing Number 551-6979212; PU-707, START/SVCR/CONT AIR, 34'-7" FLAT, FR 112-116 S.

1. INTRODUCTION

In recent years NASSCO has made considerable progress in improving their performance in ship outfitting. This improvement is leading towards achieving a level of performance, which will be competitive in international commercial shipbuilding. The implementation of on-block and on-unit outfitting techniques, together with the development of workstation-style production information and the introduction of multi-skilled work teams has significantly reduced the outfit production man-hours and cycle time. This improvement has been achieved through a wide variety of highly focused production oriented projects. In support of this project, NASSCO is building on these achievements to create a firm foundation of performance necessary to achieve international competitiveness.

This document forms part of the NSRP Project 8-98-2, Process Modeling to Improve Productivity of On-Board and On-Block Outfitting. The primary objective of the project is to establish a world-class methodology for the definition of outfit interim products. The development of a hierarchy of outfit interim products, which can be integrated with the steel structure at the optimum time in the assembly process, will significantly improve the performance of on-block and on- board vessel outfitting.

The following sections focus on implementation aspects of the outfit process model, including the outfit assembly and installation production process activities required to implement the product-oriented, approach. The following deliverables should be read in conjunction with this document:

Task 3 Deliverable – World-Class Outfit Production Process Activities,

Task 4 Deliverable – Perform Comparative Analysis between NASSCO Current and World-Class Outfit Production Process Activities, and

Task 5 Deliverable – Define Generic Outfit Process Model, and

Task 6 Deliverable – Develop Shipyard Specific Outfit Process Model.

The above documents are the basis for the development of the implementation plan for the outfit process model and should be read in conjunction with this document. The elements selected for discussion are considered to be those which are fundamental to the successful implementation of a product-oriented approach to outfit design and construction.

2. OBJECTIVE

The objective of this document is to describe the elements that were necessary to implement a pilot for a product-oriented, workstation philosophy for outfit production activities.

This implementation documentation for the chosen pilot outfit production model is developed as part of this NSRP project and has drawn on previous MARITECH Ship Factory Transformation Projects. The principal focus is on the previously identified hierarchy of outfit interim products and the production work centers and work stages of the build cycle of a ship.

3. NASSCO PILOT PROJECT IMPLEMENTATION

As was noted previously, the original technical proposal stated *"When approved by the Steering Committee, and upon award of a new ship building program at NASSCO, Project Team members will initiate the implementation process."* The fact that market conditions did not allow for implementation on a new program, the pilot would be inserted into an on going program. This made the need for a integrated implementation plan imperative.

3.1 Pilot Implementation Plan

In order to ensure a successful implementation of the pilot an implementation plan was developed by the Project Team in support of approved implementation recommendations. The Project Team coordinated and monitored the implementation process in accordance with the plan, and provided regular reports to the Steering Committee. In order to ensure a seamless insertion of the pilot into an ongoing shipbuilding program an integrated schedule of pilot and ship construction activities needed to be developed. The resulting schedule is shown in Figure 1.

The plan included meetings with the internal and external production personnel that would be building the interim products to solicit appropriate feedback into the design and the planning process. This meant that not only NASSCO personnel were involved in the project but the structural unit fabricator was included in the project in order to incorporate their specific manufacturing and fabrication processes into the design.

Along with meeting with the departments that would construct the unit, the team met with our customer that would ultimately have to operate and maintain the unit through the life of the ship. Design reviews were held with both the Military Sealift Command (MSC) and Navy representatives that were responsible for the program. Their input was included as part of the design process.

The plan also established an Industrial Engineering time study in order to evaluate the pilot and collect data needed to conduct a meaningful cost analysis. The

time study also provided a methodology for capturing lessons learned to incorporate into the feedback loop.

Production staff were also included early in the design process to provide input to the build strategy and to assist in the identification of the required production information at each stage of construction. Drawing formats were created to show planning and engineering information.

As with any new process or methodology, training is imperative. Training is not only important for the introduction of a new process into the organization but from the point of ensuring the approach is implemented in an orderly and consistent fashion. Throughout the course of the project the team members gathered and compiled both written and graphical material to be used in the training process. This training material was not focused on one individual group, but on the company as a whole. Not only would the designer need to be familiar with the outfitting process from an interim product perspective, but production would need to be aware of the modified format of the production information that would be used to construct Pipe Unit 707. Additionally, the concepts would need to be relayed to all departments within NASSCO and to all levels of the organization. This was necessary to solicit support for the current pilot along with providing information about the overall concept to facilitate appropriate decision making when it came to developing long range facility planning and anticipated manning levels along with providing information to cost engineering for marketing purposes.

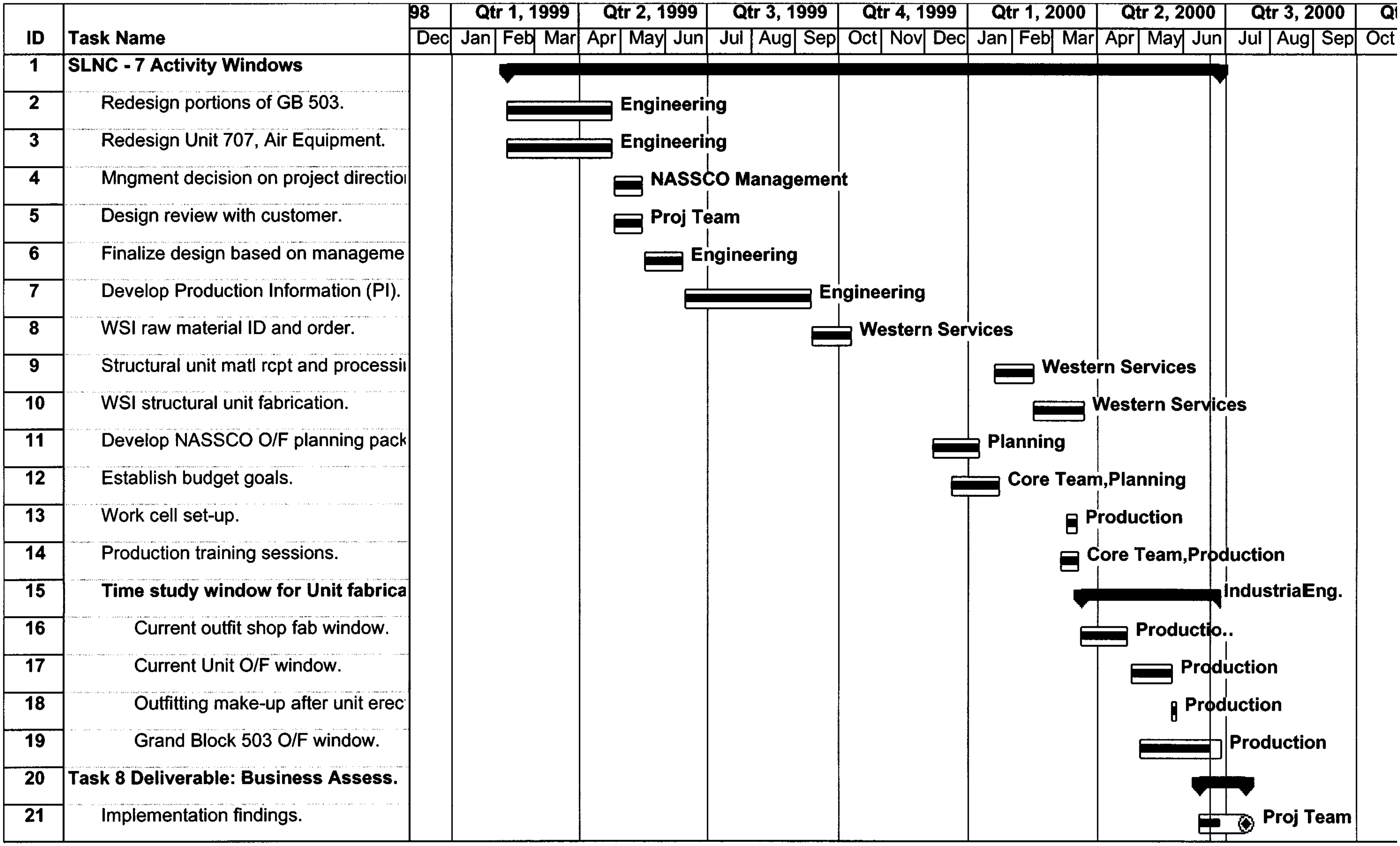


Figure 1 Implementation Schedule

4. PRODUCTION INFORMATION

The design and engineering functions are responsible for generating the majority of the information required to construct a vessel. Therefore, the methodology and process of developing the design and production information for a vessel is vital in achieving efficient production. To successfully implement an interim product concept, the design and engineering process must be product based. That is to say, a hierarchy of interim products needs to be developed which optimize the production process lanes and workstations. Task 6 identified the specific product hierarchy that was chosen for this pilot and thus laid the groundwork for the subsequent production information that would be needed by the workstations building the products.

As stated earlier, the design and engineering functions are responsible for the development of a functional and production friendly design. This includes information provided at the right time and in the right format for the end user. To achieve this it is essential to have a clear definition of the design process and the inputs and outputs at each stage. Through the application of the shipbuilding strategy approach designers and engineers have a clear definition of interim product types which optimize the production process and the design criteria for these products at each stage of the design. Given this information, designers and engineers can better develop a design which balances the requirements of the owner and production without the direct involvement of a separate production engineering function which in some cases can increase the design lead time.

The production information that was developed for the pilot was laid out with the constraints of an existing program and facility. However, it took into account the need for a product oriented approach. Appendix A is the production information that was developed for fabrication of the structural unit at a sub contractors facility. In addition to this drawing, a series of fabrication standards was also developed based on the vendor fabrication processes and facility. These accompanied the drawing and were called out as standard details.

Appendix B is the production information that was developed for the outfitting of the unit.

All interim products, pre-production and production, are assigned to specific workstations. The shipbuilding strategy defines the workstation attributes in terms of facility constraints, labor utilization and product design parameters. In most cases more than one workstation will be identified as being capable of producing an interim product. Depending upon the production work schedule, a product may be assigned to either workstation. The key to developing workstation instructions is to supply only that information required for the worker to complete the task defined for that workstation. Unnecessary information or information relevant to previous or subsequent stages will lead to confusion and reduced production control.

The format and content of workstation information must be fully developed for all pre-production, production and production support workstations. The format and content of production information is important in developing a stable and controllable production processes. Work instructions must be specific for the production workstation without a need for any shop floor interpretation. Each workstation must be supplied with, the right material and the right information at the right time. To implement this, the design and engineering personnel must know the products that can be efficiently manufactured, the process involved in the manufacture and the constraints of the facilities.

In a workstation environment there can be a considerable number of sets of work instructions required to complete an interim product from manufacturing through assembly and installation to testing and commissioning. The format and content of these work instructions are dictated by the specific processes, equipment and tooling of the workstation. These vary from workstation to workstation even when workstations produce similar interim products. The format and content of production information for all workstations is contained in the shipbuilding strategy and therefore directly transferable to a specific ship model. This also includes supplier information format which the shipyard may have to transpose to meet the workstation needs.

There are many ways of releasing work instructions to production, from simple

drawings and lists to sets of computer instructions on tape, disc or direct real-time computer links. Whichever way the instructions are issued they must be complete and unambiguous. There must be no need for a production worker to leave a workstation to look for additional work instruction. Therefore, it is extremely important to clearly define the operations of every workstation and the format and content of information required.

Clearly, the preparation of workstation information has significant impact on the shipyards planning systems and methods. The traditional approach of deciding where a product is to be built after the production information is produced is no longer valid. The workstation must be identified before the workstation information is developed. This will mean a major restructuring of the planning function where traditional post-engineering planning systems are applied.

5. THE FUTURE OF PRODUCTION INFORMATION

The development of the production information for the future incorporates integrated technology principles for development, control and access of all ship information. It is intended that this is contained in a single product model and accessed by the various workstations throughout the shipyard. As different functions require information with different formats and content such as graphic models, 2D representations and digital data it is intended that the product model will identify the format of the information required from the workstation access code, retrieve it from the product model and automatically display the information in the required format. Consequently, it is important to define the format and content of information for each workstation throughout the yard. This includes pre-production, production and production support functions.

The design process must be frequently examined for ways of improving performance and generating and issuing information. However this must be done in a consistent, structured and formalized manner. The traditional approach of "I have an idea" must be discouraged. In other industries automatic development and issuing of production information through integrated technology systems is being implemented and is leading to paper-less industries. This must be the aim in shipbuilding. There are many examples of automatic production information generation in shipbuilding today for example, pipe manufacture, cable routing and steel part nesting. In the future software packages will be developed to create all production information from an integrated product model. In addition, the development of rule-based parametric design will automate much of the design process.

Similarly, there are many opportunities in the production processes which will reduce the levels of interpretation of information between workstations. In future linking workstation attributes such as the format and content of information to the interim product model will mean that workstation information will be generated automatically depending upon the specific workstation requirements.

In the future, it will become possible to provide production information with direct computer links to the workstations through integrated technology using workstation mounted view screens or direct robot drives. In this environment the generation and supply of information becomes the critical element in the efficiency of the shipbuilding process as it directly manages and controls the production process.

Appendix A – COMSC (Commander Military Sealift Command) Drawing Number 185-6979211; SU-707, START/SVCR/CONT AIR, 34'-7" FLAT, FR 112-116 S.

Appendix B – COMSC (Commander Military Sealift Command) Drawing Number 551-6979212; PU-707, START/SVCR/CONT AIR, 34'-7" FLAT, FR 112-116 S.

Appendix A and B has not been attached with the distribution of this deliverable. It has been issued through the current document distribution process.

NATIONAL STEEL AND SHIPBUILDING COMPANY
A GENERAL DYNAMICS COMPANY

NSRP PROJECT 8-98-2

Process Modeling to Improve Productivity of On-Board and On-Block Outfitting

Task 8 Deliverable

Business Assessment

FIRST MARINE INTERNATIONAL LIMITED

SEPTEMBER 2000

Business Assessment

CONTENTS **Page**

1 INTRODUCTION

In recent years NASSCO has made considerable progress in improving their performance in ship outfitting. This improvement is leading towards achieving a level of performance, which will be competitive in international commercial shipbuilding. The implementation of on-block and on-unit outfitting techniques, together with the development of workstation-style production information and the introduction of multi-skilled work teams has significantly reduced the outfit production man-hours and cycle time. This improvement has been achieved through a wide variety of highly focused production oriented projects. In support of this project, NASSCO is building on these achievements to create a firm foundation of performance necessary to achieve international competitiveness.

This document forms part of the NSRP Project 8-98-2, Process Modeling to Improve Productivity of On-Board and On-Block Outfitting. The primary objective of the project is to establish a world-class methodology for the definition of outfit interim products, which can be competitively assembled and installed on a vessel in a multi-trade work environment. The development of a hierarchy of outfit interim products, which can be integrated with the steel structure at the optimum time in the assembly process, will significantly improve the performance of on-block and on- board vessel outfitting.

The following sections focus on the business assessment aspects of the outfit process model, including the outfit performance metrics and cost analysis methodology to be employed in the product-oriented, ship factory. The following deliverables should be read in conjunction with this document:

Task 2 Deliverable – Document Current Outfit Production Process Activities,

Task 3 Deliverable – World-Class Outfit Production Process Activities,

Task 4 Deliverable – Perform Comparative Analysis between NASSCO Current and World-Class Outfit Production Process Activities, and

Task 5 Deliverable – Define Generic Outfit Process Model, and

Task 6 Deliverable – Develop Shipyard Specific Outfit Process Model.

Task 7 Deliverable – Implement Improved Outfit Process Model,

The above documents are the basis for the development of the business assessment for the outfit process model and should be read in conjunction with this document. The elements selected for discussion are considered to be those which are fundamental to a successful business assessment of a product-oriented approach to outfit design and construction.

2 OBJECTIVE

The objective of this document is to describe the logic for identifying performance metrics together with a methodology for cost analysis. The product oriented workstation philosophy described in the methodology template forms the basis for defining the metrics which, together with other product attributes, are embodied in the company shipbuilding strategy.

The careful selection of appropriate performance metrics not only enables a close monitoring of current contract performance it also provides up to date information for the estimating of potential new contracts. Used as an integral part of a production work packaging system, performance metrics are the means of monitoring overall yard and individual workstation performance.

Accuracy of budgeting, scheduling and performance monitoring are crucial and set the framework for controlling operations at all levels and stages of construction. The selection of suitable metrics is determined by developing a series of performance measurement criteria. The following sections describe a methodology for defining performance metrics.

3. SELECTION CRITERIA FOR PERFORMANCE METRICS

To enable accurate interrogation and manipulation of performance data it is important that performance metrics should be:

- simple and easily identified, not based on complex mixes of attributes,
- consistent and traceable from initial contract estimating to workstation work packages,
- capable of hierarchical interrogation, and
- progressively developed through the design and engineering process.

The methodology template describes a product oriented organization and in this environment, to enable the development of performance metrics there must be a well-structured and clearly defined hierarchy of interim products for all product types in the construction process. The products are defined in the shipbuilding strategy and include vendor supplied equipment. In addition to the physical configuration of the interim products, the shipbuilding strategy also includes all associated process and performance attributes. The methodology for the development of outfit interim products and their attributes is described in the "Generic Outfit Process Model".

In order to develop an optimum interim product structure it is essential to define and document the associated production processes to the level of individual workstations. Each workstation must have a clearly defined set of performance attributes for each product family which define all capabilities and constraints. The methodology for the development of the production process definition is described in the "World Class Outfit Production Process Activities".

As mentioned earlier, performance metrics are an integral part of a structured labor cost control system. It is therefore important that performance metrics and the associated rates accurately report performance data from individual workstations.

Workstation performance data must recorded at a suitable level of detail for weekly performance monitoring of interim product throughput. The data must also be structured hierarchically so that it can be interrogated to provide performance information by cost center,

ship system and total ship. The ability to rapidly record and interrogate performance on a weekly basis is essential for the cost control of current contracts as well as the estimating and planning of future contracts

In summary, it is extremely important that the performance metrics are compatible with the production processes and do not need unnecessary interpretation for input to the data system. Equally important, the work content should be capable of being readily extracted from the design and engineering process though a series of interim product attributes which are interrogated by means of a structured coding system. Ideally this is developed as part of an integrated technology system and embodied in the company shipbuilding strategy which eliminates the necessity of interpreting workstation performance data into useable data for estimating and production control.

4. SELECTION OF PERFORMANCE ATTRIBUTES

Appropriate performance metrics enables a company to set performance targets and to consistently monitor performance at all stages throughout the pre-production and production operations (see figure 1). However, it is important that the process of performance monitoring and updating of the applied performance rates involves a minimum of time and man-hours. Similarly, actual performance information should be readily available in a format relevant to the end user without any manual interpretation. Ideally, through direct computer link to the production control system without the need for hard-copy.

To this end, it is important that performance budgeting and monitoring is an integrated part of the estimating, design, engineering and construction process. Also, if the shipyard performance is to be compared with other yards, the performance data needs to be capable of interpretation into more global performance metrics than those needed for internal production control.

To be effective, a performance metric must be based on a 'work content' value that is capable of being developed as a bye-product of the design and engineering process. Ideally this should be generated automatically from the interim products and type plans which are part of the company shipbuilding strategy. Work content information must be:

- hierarchically structured such that it is capable of progressive refinement through the design and engineering process, and
- consistent across all interim product types.

There are a variety of attributes which can be effectively used as performance metrics. In global terms many shipyards use man-hours/CGT as readily calculable means of international benchmarking. However, in a yard constructing unique ship types the accuracy of man-hours/CGT depends upon the CGT factor used and should only be used as a very high level performance indicator. Other commonly used high level performance metrics include:

- man-hours/CAD model in design and engineering,
- man-hours/ton for structural steelwork,
- man-hours/trade by stage of construction

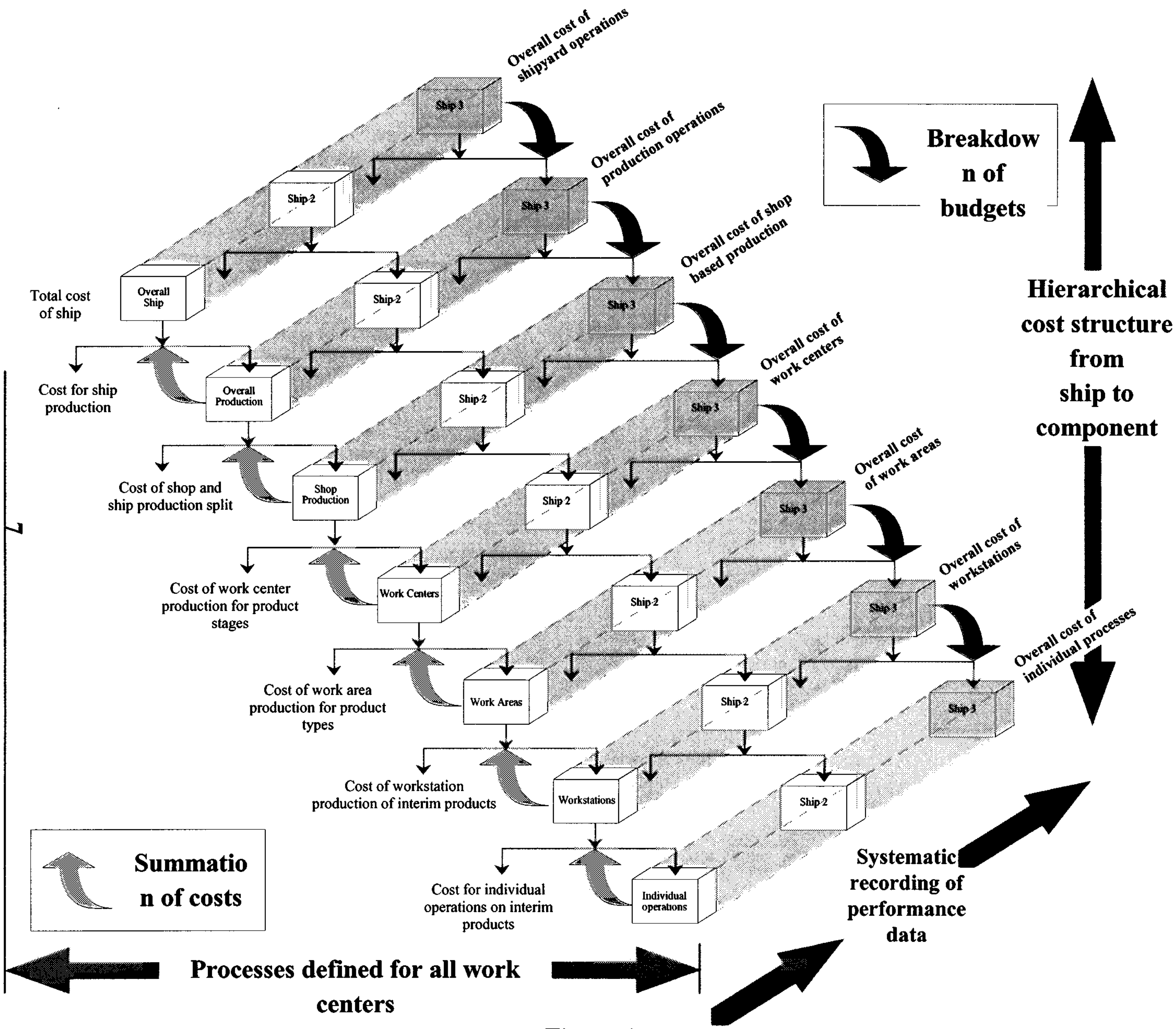


Figure 1

Heirarchical structure for budgeting, cost recording, cost summation and performance analysis

In a product oriented environment the most applicable and readily useable metric is man-hours and cycle time per interim product. By attaching other attributes to a clearly defined range of interim products such as ship, weight, system, trade percentage involvement and workstation preferences product performance data can be interrogated to provide a variety of alternative performance indicators.

5. AVAILABILITY OF WORK CONTENT INFORMATION

The timeliness and structure of design and engineering information is the principal driver in an integrated technology system applying a shipbuilding strategy concept. Production performance attributes are assigned at each stage of the design and engineering process. At the concept stage only the highest level of performance metric is applied such as man-hours/trade and man-hours/ship system. The metrics are progressively refined as the design is developed to the level of workstation information but are hierarchically traceable to the highest level. This infers a clearly defined structure for the development of the ship product model. In addition to the progressive assignment of production performance attributes, the design and engineering process must also be structured so that similar and consistent metrics can be applied for pre-production performance. For example, at the initial design stage man-hours and cycle time per ship system can be used and at the detail engineering stage man-hours and cycle time per interim product can be used.

Attributes are attached to the various interim product models as part of the data required throughout the design and build process. Many of these attributes have multiple uses throughout the design, planning and production processes. For example, weight is used in design calculations, material handling and as a prime estimating and planning mechanism. Similarly, lengths of individual pipe systems are used in fluid flow design as well as the estimating and planning activities. Thus, much of the data needed for the performance metrics is readily available and can be extracted without additional effort.

5.1 Identifying the types of performance metric

The estimating function will generally apply a system based work content metric to determine the various components of ship cost as design information available at an early stage will invariably be system oriented. Therefore, for traceability throughout the design, engineering and production process it is desirable to maintain a system link which enables a direct comparison with the estimate at all stages of a contract (see figure 2) For example a high level system based metric may be:

- Main structure systems - hull, decks, bulkheads - work content based upon material, thickness, area and weight.

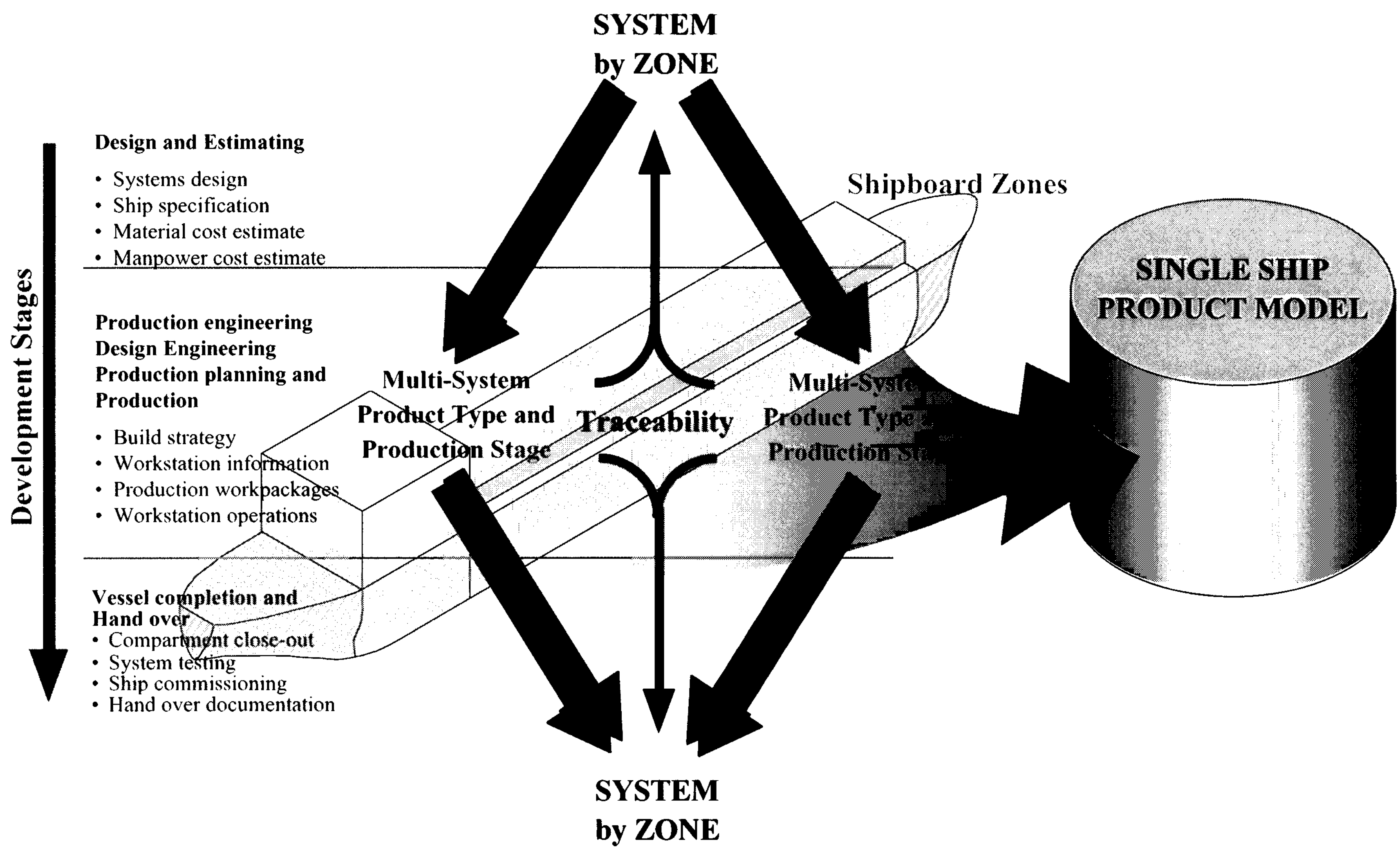


Figure 2

Traceability Capability within

Single Ship Product Models

- Services systems - piping, electrical, ventilation - work content based upon type of system, material, length of run and diameter.
- Hotel systems - ceiling, floors, internal bulkheads, furniture – work content based upon type, area and quantity.
- Equipment - main machinery, ancillary equipment, deck equipment - (if not included in services systems) - work content based upon type, weight and power.

System based metrics are commonly used throughout the industry and there are a number of proprietary system identification publications available. The two most common being the SWBS system in the USA and the SFI system in Europe.

For production planning and scheduling an interim product based metric such as man-hours and cycle time is most commonly used. In a workstation environment using workstation information data for interim products is readily available from the engineering process. However, as shown in figure 2, it is important to maintain system traceability through multi-system interim products. This link is achieved through the work packaging system structure.

Typical examples of interim product metrics are:

- Main structure and outfit steel – by defined hierarchical product type for manufacturing and assembly using weight,, cut length,, joint length, and weld volume.
- Piping – by interim product quantity for each type and size in the manufacturing process and weight and quantity in the assembly process.
- Ducting – by interim product quantity for each type in the manufacturing process and weight and quantity in the assembly process.
- Electrical – by weight, quantity and length for each type and size of interim product in the manufacturing and assembly processes.
- Main engine – by weight of equipment for erection and by numbers of chocks for fitting
- Furniture - by weight and quantity for each type and size of product in the manufacturing and assembly process.
- Fittings - by weight and quantity for each type and size of in the assembly process.
- Painting - by area and number of coats for each type and size of product.
- Insulation - by area for each of the types and size of product.
- Linings & ceilings - by area, weight and quantity for each type and size of product.
- Commissioning & Testing – by type of system.

In an environment, where the company has clearly defined and stable production processes along with a fully defined range of interim products the design of a new vessel can be rapidly achieved through the application of the defined interim products in a unique aggregation. This will also generate accurate cost, planning and scheduling information much earlier in the design and engineering process.

6. USE OF ALTERNATIVE PERFORMANCE METRICS

With stable production processes and consistent interim product types it becomes possible to simplify the work content calculations. For example, with a clearly defined interim product range with known and proven performance attributes it is sufficient to calculate the number of interim product types thereafter the database can provide workstation loading and contract performance data. However, care must be taken to ensure process stability before attempting to simplify the performance metrics otherwise the production control system will be ineffective.

The following are examples of alternative 'work content' information that is readily available from the design and engineering process and which may be used in a stable production environment.

- Number of interim products
- Weight of the product.
- Joint configuration and orientation.
- Weld volume

In the above, the number of interim products is the main performance metric with weight, joint length and weld volumes as more detailed work content options. Each can be used in analyzing a production process, but not all are equally applicable to all interim products. For example the weight of an outfit unit at erection has less value in terms of work content measurement at the joint configuration and orientation.

This emphasizes the need for clearly defined and structured product attribute data which can be attached to the individual interim products in the shipbuilding strategy database. In a similar manner performance attributes are attached to the production or workstations.

7. COST ANALYSIS METHODOLOGY

Cost benefit analysis of alternative design solutions is an essential part of the design and engineering process. The analysis should be readily available on an interactive basis to designers and engineers. Applying the shipbuilding strategy philosophy cost analysis information is an integral part of the interim product attributes. This not only enables the setting of performance targets but also enables the definition of how they will be achieved.

For the process to be effective it is essential that before introducing a new interim product, all attributes are clearly and accurately defined and performance rates calculated for existing or new production workstations. New interim product types should not be introduced unless they are agreed and included in the shipbuilding strategy.

7.1 Calculating the cost of interim products

The cost analysis process is straight forward, and relies on having accurate attribute information. Preferably this information is provided automatically from the interim product and process models. Development of attribute information is described in previous documents. The stages in determining the cost of the interim products is shown in figure 3.

The first stage in the process is the definition of the appropriate production process flow for the manufacture of the various outfit part product types. These are then matched to preferred assembly types in the hierarchy of minor, sub, unit, block and joint assemblies also to zone completion and testing.

The second stage is to quantify the number of assemblies and parts associated with each stage using interim product flow charts. This data is compiled to form the product summary and contains appropriate product work content attributes for assemblies and part types. This forms the base product information for the cost analysis.

The third stage is to match the interim products to their respective production processes and workstations. Each workstation has a set of performance rates, which match the interim product attributes. The resulting combination of product work content and production process rates give the cost of products for a particular design solution.

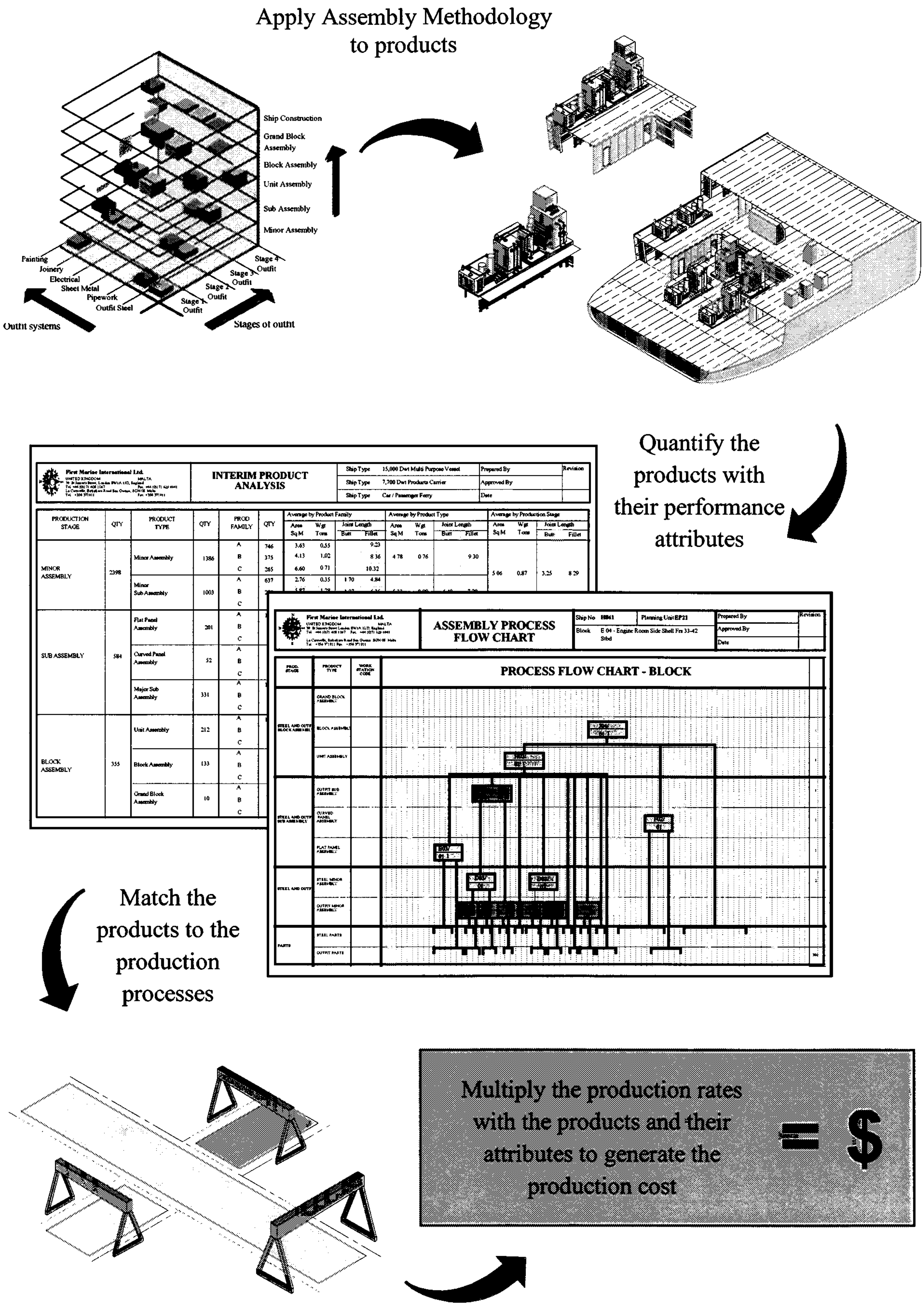


Figure 3
Methodology for generating the cost of interim products

8. SUMMARY

NASSCO's long range goal is to reduce cost and cycle time to increase competitiveness. This type of a goal will require continuous improvement in all areas. Based on this project, incremental improvement over the normally expected learning curve is anticipated through:

- incorporation of design improvements and establishment of a stable and consistent product hierarchy
- reapportionment of work to the optimum work center
- reduction in the number of hangers by incorporating the function into product structure
- processes accomplished in a work center dedicated to those processes
- production information dedicated to the work cell

Finally, to achieve the goals it is important to ensure all developments in products, processes, skills and knowledge is harnessed in a consistent manner leading towards a common goal. It must be remembered that whenever, one part of the shipbuilding equation changes then the rest must change to balance the overall process.

For more information about the
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